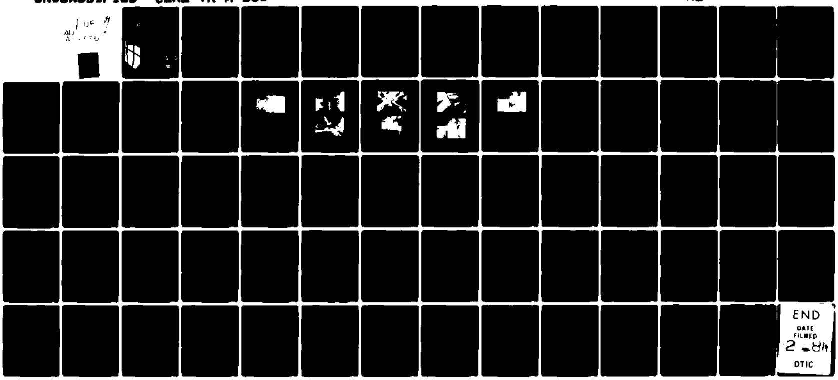
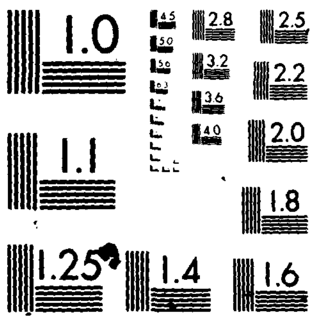
AD-A093 761 CONSTRUCTION ENGINEERING RESEARCH LAB (ARMY) CHAMPAIGN IL F/G 13/2
PAVEMENT EVALUATION AND REPAIR RECOMMENDATION SIERRA ARMY DEPOT--ETC(U)
NOV 80 M Y SHAHIN IAO-PR-9-80

UNCLASSIFIED CERL-TR-M-283 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

12

construction
engineering
research
laboratory

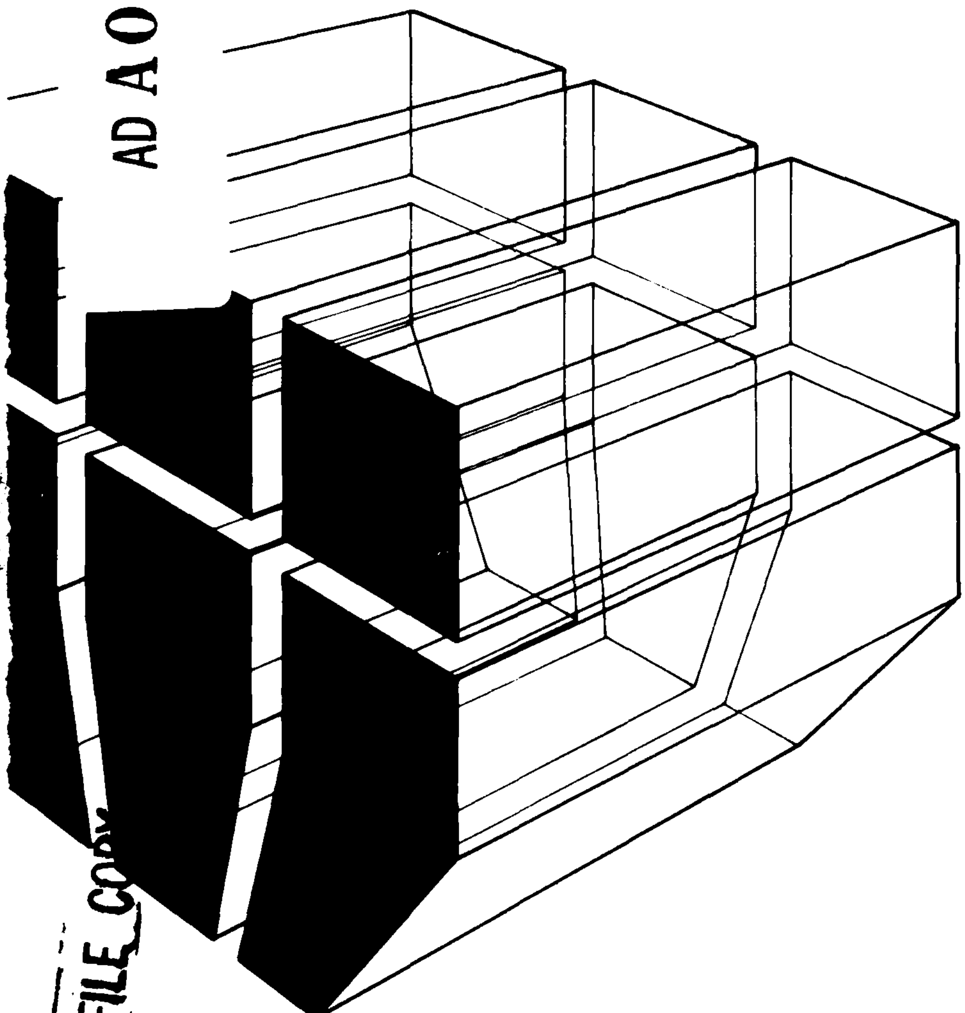
United States Army
Corps of Engineers
...Serving the Army
...Serving the Nation

TECHNICAL REPORT M-283
November 1980

LEVEL II

AD A093761

PAVEMENT EVALUATION AND REPAIR RECOMMENDATION SIERRA ARMY DEPOT, AMEDEE AIR STRIP



M. Y. Shahin

DTIC
SELECTE
JAN 13 1981
S D
C

CERL

DDC FILE COPY

Approved for public release; distribution unlimited.

81 1 13 007

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official indorsement or approval of the use of such commercial products. The findings of this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

DESTROY THIS REPORT WHEN IT IS NO LONGER NEEDED
DO NOT RETURN IT TO THE ORIGINATOR

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER (14) CERL-TR-M-283	2. GOVT ACCESSION NO. AD-A093 761	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) (6) PAVEMENT EVALUATION AND REPAIR RECOMMENDATION SIERRA ARMY DEPOT, AMEDEE AIR STRIP		5. TYPE OF REPORT & PERIOD COVERED (9) FINAL rept. 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) M. Y. Shahin (10) Mohamed Y. Shahin		8. CONTRACT OR GRANT NUMBER(s) (15) IAO-PR-9-80
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. ARMY CONSTRUCTION ENGINEERING RESEARCH LABORATORY P.O. Box 4005, Champaign, IL 61820		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (12) 66
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE (11) Nov[redacted]980 13. NUMBER OF PAGES 62
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Copies are obtainable from National Technical Information Service
Springfield, VA 22151

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Sierra Army Depot, CA
Amedee Air Strip
runways
pavements
maintenance
repair

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Pavement Condition Index (PCI) procedure was used to evaluate five alternatives for repairing the runway of the Amedee Air Strip, Sierra Army Depot, California. Based on the PCI analysis, it was recommended that the old surface be recycled and used as a base, with a new asphalt concrete surface added to a depth of 3 inches at the central 75 feet and tapered to 1 inch at the edges. This recommendation was based on the assumption that the engineer has flexibility in specifying the type and grade of asphalt needed. If not, reconstruction with concrete may be economically justified based on life cycle costs.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

JCP

410279

FOREWORD

This research was conducted for the Sierra Army Depot, Herlong, CA, under IAO PR 9-80 by the U.S. Army Construction Engineering Research Laboratory, Champaign, IL. The Sierra Army Depot Project Monitor was Mr. Michael P. Balerviez. The CERL Principal Investigator was Dr. M. Y. Shahin.

The following people are acknowledged for their participation in surveying the runway: Mssrs. Mike Flaherty and Jim West, DARCOM; Mssrs. Mike Balerviez, Ray McMillan, and David Wickward, Sierra Army Depot. Dr. R. Quattrone is Chief of CERL-EM. COL Louis J. Circeo is Commander and Director of CERL, and DR. L. R. Shaffer is Technical Director.

Accession For	
NTIS GRA&I	☒
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A	

CONTENTS

FIGURES

TABLES

PAVEMENT EVALUATION AND REPAIR RECOMMENDATION SIERRA ARMY DEPOT, AMEDEE AIR STRIP

1 INTRODUCTION

Background and Description of Existing Facility

Amedee Air Strip is located at Sierra Army Depot, Herlong, California, east of Honey Lake and 50 air miles northwest of Reno at an elevation of 4000 feet.

A layout of the runway is shown in Figure 1. The runway surface is a 3-inch layer of asphalt concrete (AC) which, with the 4-inch crushed base below, was added in 1969. The original runway was constructed in 1943, and the 1969 overlay was emplaced because of considerable cracking in the original surface. The 4-inch crushed stone base was used to eliminate (or minimize) reflection cracking in the new surface.

Since its overlay in 1969, the runway has had a history of problems, and experts from Office, Chief of Engineers (OCE), Sacramento District Engineer Office, Defense Acquisition and Readiness Command (DARCOM), Depot Systems Command (DESCOM), and the U.S. Army Corps of Engineers Waterways Experiment Station (WES) have made on-site evaluations of its condition. These evaluations showed that although the runway appears to be structurally sound, the pavement has oxidized, causing surface cracks. It was also concluded that the cracks are not reflective cracks from the old pavement constructed in 1943.

The cost of maintaining the runway from 1969 to 1979 has been $320,550, and is increasing rapidly.

Objective

The objective of this study was to determine the optimum maintenance and repair alternative for Amedee Airfield.

2 INVESTIGATION

Runway Condition Survey

On 13-15 November 1979 a team from DARCOM, the Sierra Army Depot, and CERL performed a condition survey of the runway using the Pavement Condition Index (PCI) procedure developed by CERL and implemented by the U.S. Air Force worldwide.[1] The runway was divided into distinct features based on structural composition and traffic distribution as shown in Figure 2. Each feature was divided into sample units for inspection. The number and location of sample units inspected were determined as shown in Figure 3. A PCI inspection was performed on all the runway features, and the results are shown in parentheses in Figure 2. Figure 4 shows a plot of the PCI for the individual sample units of each feature, and Appendix A provides a complete PCI computer output.

The results of the PCI survey (Appendix A) showed that the distress is mostly linear cracking. Figure 5 is a photograph of the runway surface. Table 1 summarizes the quantities and severities of linear cracking found in each feature and Table 2 summarizes the other distresses that were found.

Field Investigation

From the PCI inspection, it was determined that the majority of the cracks are temperature related; however, whether the distress was reflective, started from the base course (i.e., bottom-up), or started from the surface (i.e., top-down) was not clear. Therefore, three cuts (approximately 1 x 2 feet) were made around the different cracks so that their cause and characteristics could be clearly determined (Figure 6). Cuts #1 and #3 were outside the traffic area, and cut #2 was in the traffic area.

Cut #1 (Figure 7) was across a 4-inch-wide crack extending through the full depth of the top AC surface. There was no evidence of the crack in the base or on the old AC surface below.

Cut #2 (Figure 8) was made across two cracks, one of medium severity and one of low severity. Both cracks were continuous throughout the full depth of the top AC surface but not through the base or old AC surface. The low-severity crack was only about 1½ feet from the medium-severity crack and both were in the wheel path, as indicated by the tire markings. These two cracks were also beginning to be connected by random cracking. It was evident that the initial temperature cracking was becoming alligator cracking because of the weakened pavement condition around the temperature cracks.

[1] *Airfield Pavement Evaluation Program*, AFR 93-5 (Department of the Air Force, 1980).

Cut #3 (Figure 9) was made across the tip of a hairline crack in a nontraffic area. The cut showed that only portions of the crack had propagated to the bottom of the AC surface. In Cut #3, the surface crack was 8 inches long and only 3 inches had propagated to the bottom. Therefore it was concluded the crack had originated at the surface.

Based on the field investigation, it was concluded that the cracking in the Sierra Army Depot runway is limited to the AC surface. Furthermore, it was speculated that the temperature cracks are caused by thermal fatigue in the AC surface resulting from the high daily temperature cycling variation in this area.

Laboratory Investigations

The laboratory investigations were designed to verify field observations that the AC surface had oxidized and that the cracks were caused primarily by thermal fatigue cracking. The AC slabs obtained from the three cuts described above were forwarded to WES for testing. Appendix B provides the results of the testing.

Tests performed included: AC Marshall Stability, flow, percent voids in total mix, percent voids filled; and asphalt penetration, softening point, and viscosity. The results showed that the pavement had oxidized, as indicated by a penetration of 15 and softening point of 71.2°C (160°F) for the asphalt in the surface course.

Construction records from 1969 showed that the asphalt had an original penetration of 90 and a softening point of 49.4°C (121°F). The construction records also showed that penetration (percent of original) after the Thin Film Test was 72. The drop in penetration from 90 in 1969 to 15 in 1979 is considered high.

In addition to the above tests, the indirect tensile test was performed at four temperatures (-20, 20, 50, and 75°F) at loading rate .05 inches/minute, and at three temperatures (20, 50, and 75°F) at loading rate 2.0 inches/minute. Figure 10 is a plot of the tensile strength of the AC mix (top 1.5 inch) versus temperature.

To verify the cause of cracking, the program developed by Shahin[2] was used. The program predicts both low-temperature and thermal-fatigue cracking as a function of the AC mixture properties and climatic factors. Figure 11 shows the input to the program. Figure 12 is a plot of cracking versus age as predicted from the program. As shown in the figure, there is a close agreement between the measured and predicted amounts of cracking.

Detailed analysis of the program output showed that the cracks are caused by thermal fatigue cracking (resulting from daily temperature cycling) rather than just simple low temperature. The close agreement in prediction is encouraging in that the same program can be used for future mix design and selection of optimum asphalt grade to minimize cracking. It is believed that a careful mix design and careful selection of asphalt grade can increase the pavement life by several years.

3 EVALUATION

Evaluation of Past Performance and Selection of Feasible Maintenance and Repair (M&R) Alternatives

The evaluation, which was performed according to the M&R guidelines CERL developed for the U.S. Air Force,[3] was performed for feature RC3 since it is the largest feature, receives most of the traffic, and has the lowest PCI. Following is a brief discussion of the results, which are summarized in Figure 13.

1. The PCI of the feature is 61, which locates the feature in an M&R zone of routine, major, and overall. This is based on the guidelines shown in Figure 14, which were developed by a group of experienced Air Force engineers and subjected to considerable field testing and validation. It is to be noted that the M&R zone reflects needed M&R within 2 years of the PCI survey date.

2. Localized variation exists. Variation results because one sample unit has a PCI of 33 (sample unit #20), while the average PCI of the feature is 61.

3. The long-term rate of deterioration is high compared to other airfield AC pavements of the same

---

[2] M. Y. Shahin, "Prediction of Low-Temperature and Thermal-Fatigue Cracking in Flexible Pavements," Ph.D. Dissertation (University of Texas at Austin).

[3] M. Y. Shahin, *Development of a Pavement Maintenance Management System, Vol VI: M&R Guidelines—Validation and Field Applications*, ESL-TR-79-18 (USAF Engineering and Services Center [AFESC]).

age throughout the United States. This is illustrated in Figure 15.

4. Analysis of the load-carrying capacity showed the pavement to be structurally adequate (see Figure 16). Distress evaluation showed that 56 percent of the deduct value stem from load-associated distress (alligator cracking). However, this can be attributed to the weakened areas adjacent to cracks caused by temperature variations.

Application of the M&R Performance Standards recently developed for the U.S. Air Force* to the results of the evaluation in Figure 13 showed that most experienced maintenance engineers would consider the following M&R alternatives:

(a) Routine,
(b) Surface Treatment,
(c) Thin Overlay, and
(d) Recycling or Replacement of Surface.

The above alternatives all seemed feasible. Selection of a specific M&R alternative is a function of future performance and life-cycle costing.

Prediction of Future Performance of Selected M&R Alternatives

Five Specific M&R alternatives were analyzed:

Alternative A: Continue to seal cracks to a minimum (acceptable) PCI; then overlay with 3-inch AC at center, tapered to 1 inch at edges.

Alternative B: Seal cracks and overlay immediately with 3-inch AC at center, tapered to 1 inch at edges.

Alternative C: Replace entire surface with a new 3-inch-deep AC hot mix.

Alternative D: Recycle surface and reuse as base; then add new 3-inch AC for central 75 feet and taper to 1 inch at edges.

Alternative E: Replace central 75 feet of surface course with 3-inch AC hot mix, and continue to crack seal outside areas.

Along with each of these alternatives, it was assumed that a rejuvenating surface treatment would be applied periodically to retard surface brittleness and thus temperature cracking.

*U.S. Air Force Pavement Major Command Engineers meeting held at CERL 15-17 Jul 80.

The PCI for each alternative was predicted, using a computer program based on M&R consequence models developed for the U.S. Air Force.[4] Appendix C provides the program output for each M&R alternative. Figure 17 is a plot of the expected PCI over time for each alternative.

Life-Cycle Costing of Selected M&R Alternatives

The life-cycle costing is determined based on initial cost, future M&R cost, and salvage value. The present-worth method was used to consider both interest and inflation rates. Figures 18 through 22 provide work summary and initial cost estimates for each alternative.

Future cracking had to be predicted in order to estimate future M&R cost. The maximum cracking expected to occur in the future, is block cracking with an average size of 10 feet x 10 feet. This translates into a total cracking length of approximately 197,050 linear feet for an area that is 150 feet x 6800 feet. The total amount of cracking currently existing is 51,053 feet. Using statistical techniques,[5] future cracks were predicted; (see Table 3). Appendix D provides the computer output used in the prediction. Future M&R was computed on a two-year basis, assuming a repair cost of $1.0/linear foot. Another assumption in the computation of future M&R was that cracks must be resealed every 6 years. Table 3 shows all cost calculations.

For M&R Alternative E, where only the central 75 feet would be replaced, it was essential to do the crack prediction for only the outside 75 feet. Table 4 summarizes the cracking outside the central 75 feet.

The maximum cracking expected to occur outside the central 75 feet will be in the form of block cracking having an average size of 10 feet x 10 feet, or a total

[4] M. Y. Shahin, M. I. Darter, and T. T. Chen, *Development of a Pavement Maintenance Management System, Vol VII: Maintenance and Repair Consequence Models and Management Information Requirements*, ESL-TR-79-18 (AFESC, December 1979)

[5] M. Y. Shahin, M. I. Darter, and S. D. Kohn, *Development of a Pavement Maintenance Management System, Vol IV: Appendices A through I, Maintenance and Repair Guidelines for Airfield Pavements*, CEEDO-TR-77-44 (AFESC, 1977).

cracking length of approximately 105,325 feet. The total cracking currently existing is 18,906 feet. Using statistical techniques, future cracks were predicted (see Table 5). Appendix D provides the computer output used in the prediction. Another assumption in the computation of future M&R was that cracks must be resealed every 6 years. Table 5 shows all cost calculations.

The information in Tables 3 and 5 was used to compute future M&R costs for each alternative. (Appendix E shows the computation of future costs.) The cost information was then input to a present-worth economic analysis program. Figure 23 shows the results of the cost analysis, with ranking of alternatives based on net present cost shown at the top of the figure. Considering the amount of predictions and estimates involved, the difference in cost among the various alternatives is not large enough to allow selection of an alternative based on cost alone.

4 CONCLUSIONS AND RECOMMENDATIONS

The runway AC surface had oxidized, as shown by a measured asphalt penetration of 15 (1979) versus an original penetration of 90 (1969). Large daily temperature variations (average daily temperature range of 40°F) have caused the oxidized AC surface to crack. The amount of cracking is expected to increase at a high rate, as predicted in Table 3.

Figure 2 shows the PCI of the various runway features. The lowest PCI is 61 for feature RC3, which has been caused by further breakdown of the cracks under load.

Five feasible M&R alternatives were identified and analyzed. Figure 17 shows the performance (PCI over time) expected for each alternative. Figure 23 shows the results of life-cycle costing for each alternative. The most costly alternative (C) is only about 30 percent higher than the least costly alternative. Therefore, considering the amount of predictions and assumptions necessary to perform the life-cycle costing, the difference in net present cost among the various alternatives cannot be used as a sole indicator for selecting the best alternative. Another factor to consider is the dollars spent per unit performance. This is computed by dividing the net present cost for each alternative by the area between the PCI (Figure 17) and the minimum acceptable PCI during the analysis period (1980 to 2000). Table 6 shows the results of these computations. Although the differences are still narrow, alternatives B, D, and E appear to be more advantageous.

Based on the overall analysis, it is recommended that alternative D be adopted; i.e., recycle surface, reusing it as base, then add new 3-inch AC for the central 75 feet, and taper it to 1 inch at the edges. Alternative D is recommended, because it offers the following unique advantages:

1. It is the strongest alternative structurally of great importance in case of the heavy traffic operations.

2. It requires the least amount of future maintenance and thus less frequent traffic interruptions.

3. It will eliminate the possibility of reflection cracking by recycling the surface and using it as a base.

4. It provides an environmental advantage because of recycling.

It is recommended that alternative D be implemented within the coming 3 years (1981 to 1984).

It must be emphasized that any new AC mix should be carefully designed to minimize temperature cracking. Special attention should be given to the asphalt grade and specifications. Acceptance of the mix should be based on analysis similar to that described in the section on "Laboratory Investigation".

The asphalt selected should have a penetration of approximately 120 and percent penetration after the thin film oven test of 65-75. If no asphalt supplier in the area can meet the required specifications, then consideration should be given to reconstructing the runway with concrete. Concrete was not analyzed in detail, since the initial cost was estimated to be four times that of alternative D. However, if no asphalt supplier can meet the requirements to minimize cracking, then reconstruction with concrete may be economically justified based on the life cycle costs.

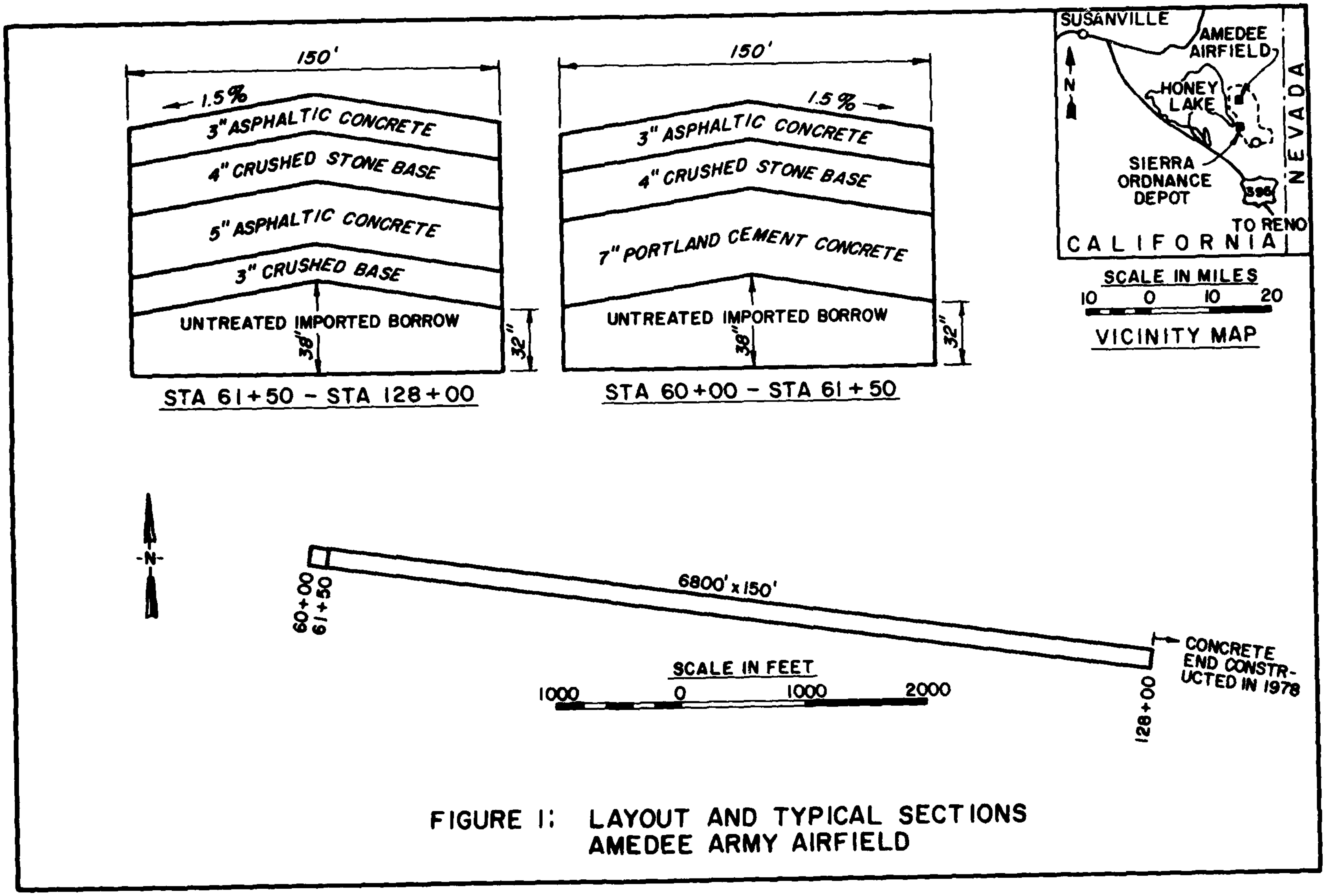


Figure 1. Layout and typical sections Amedee Army Airfield.

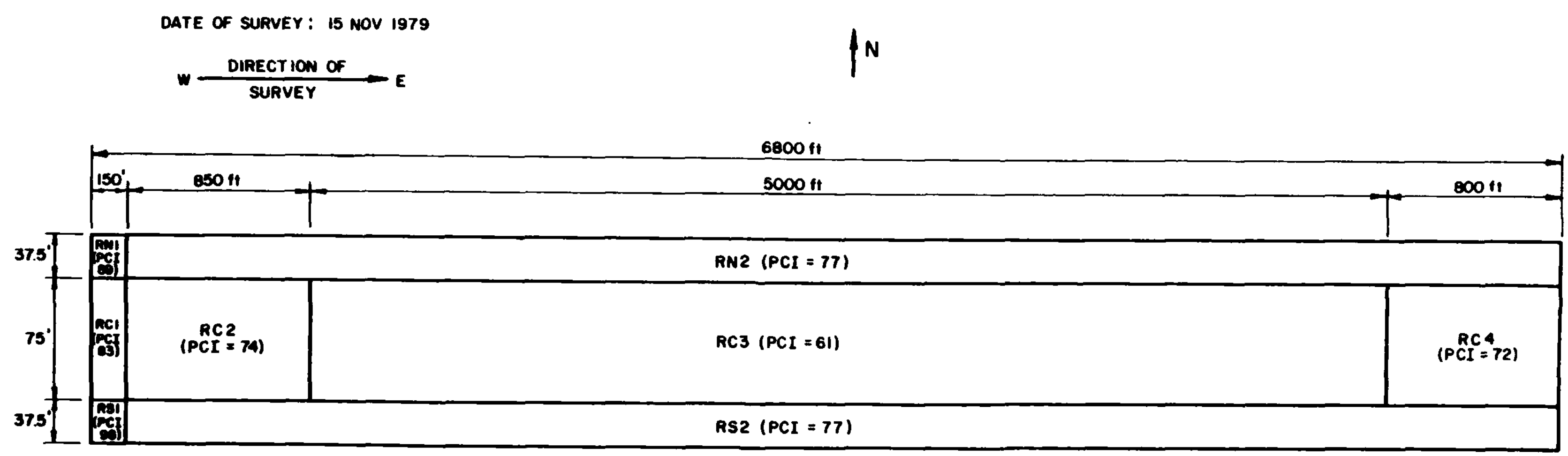


Figure 2. Division of runway into features.

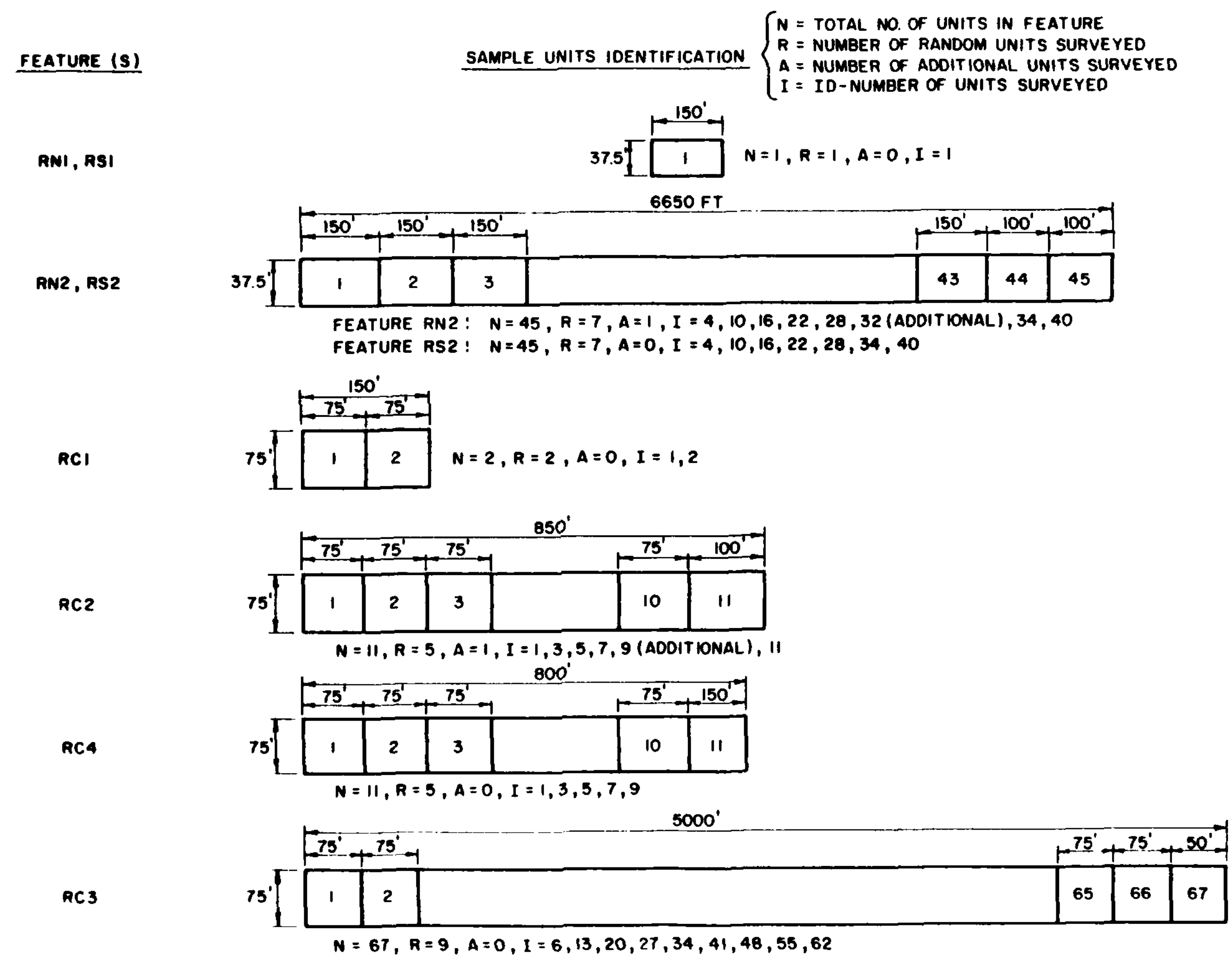


Figure 3. Division of features into sample units.

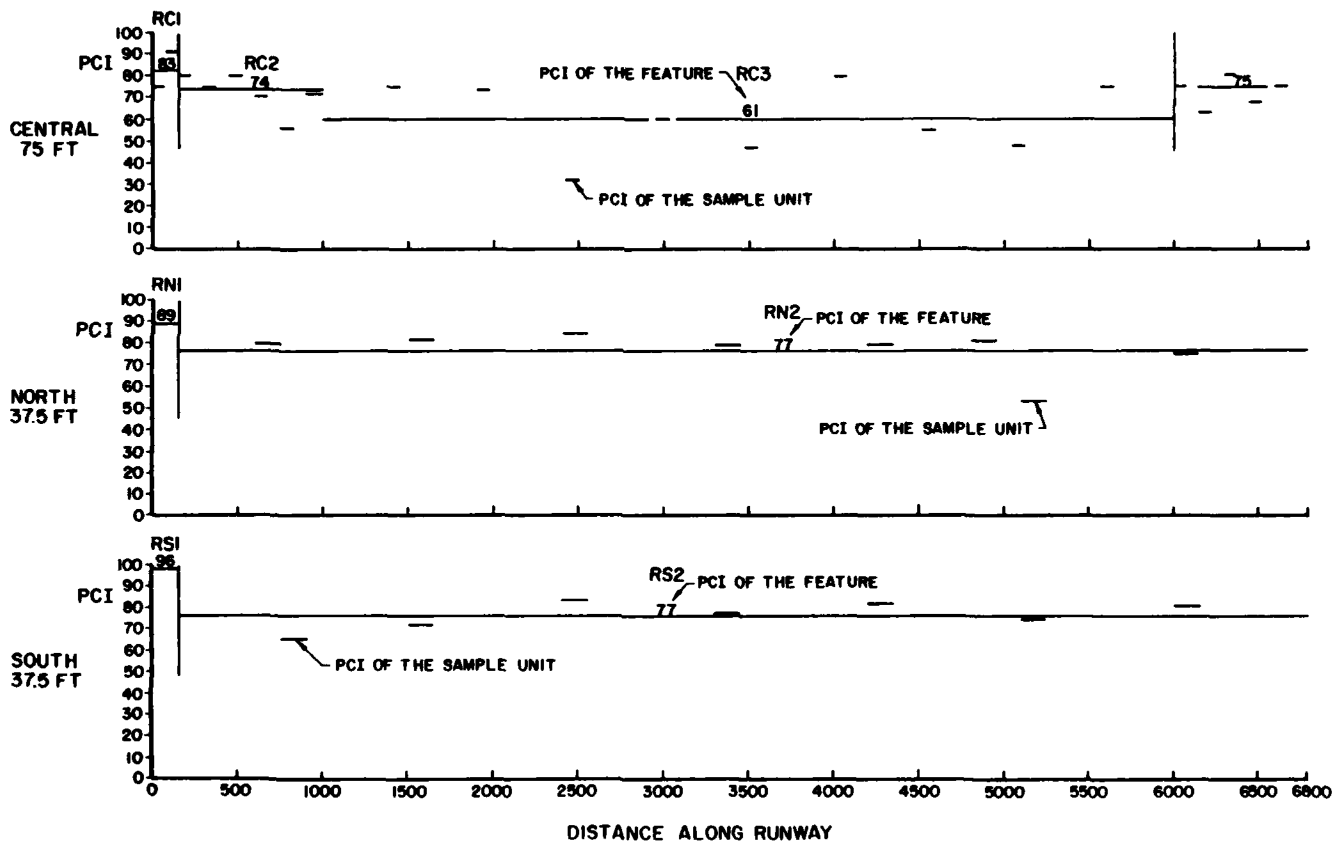


Figure 4. PCI of individual sample units for central, north, and south features.

Figure 5. Photograph of Sierra Army Depot, Amedee Runway, showing primary type of distress (temperature cracking).

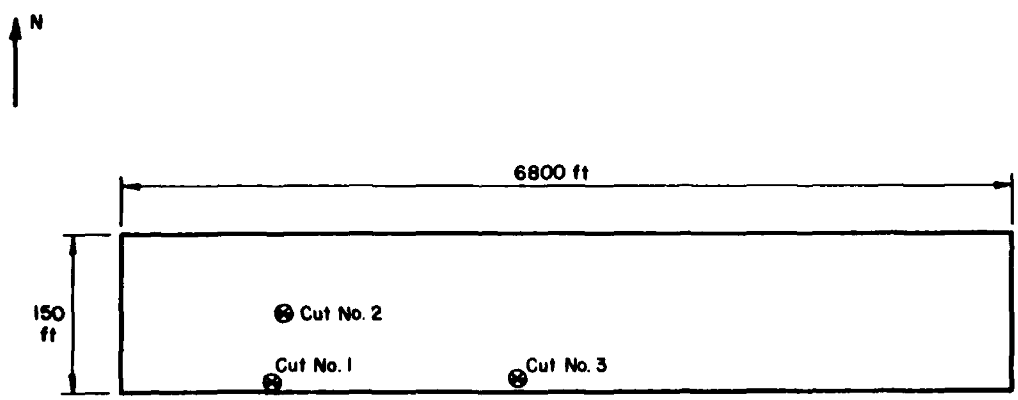
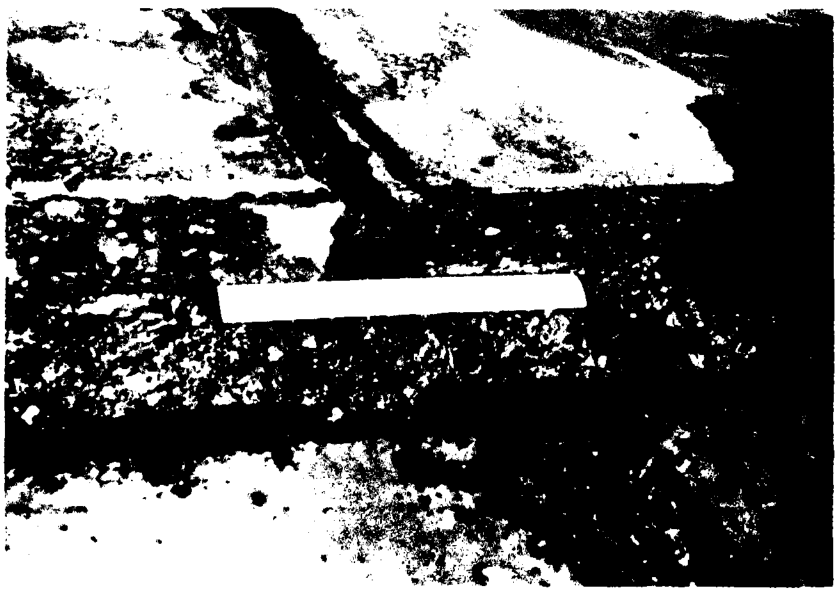


Figure 6. Runway layout showing location of cuts.

(a) Pavement before cut showing 4-inch wide crack.



(b) Pavement after cut showing crack to extend through the full depth of the top AC surface.

Figure 7. Cut #1.

(a) Cut showing medium and low severity cracks.

(b) Bottom of pavement slab. Cracks were found to extend through the full depth of the top AC surface.

Figure 8. Cut #2.

(a) Pavement slab being carefully lifted after saw cutting.

(b) Top of slab showing 8-inch-long crack.

Figure 9. Cut #3.

(c) Bottom of slab showing 3-inch crack propagated to bottom.

Figure 9. (continued)

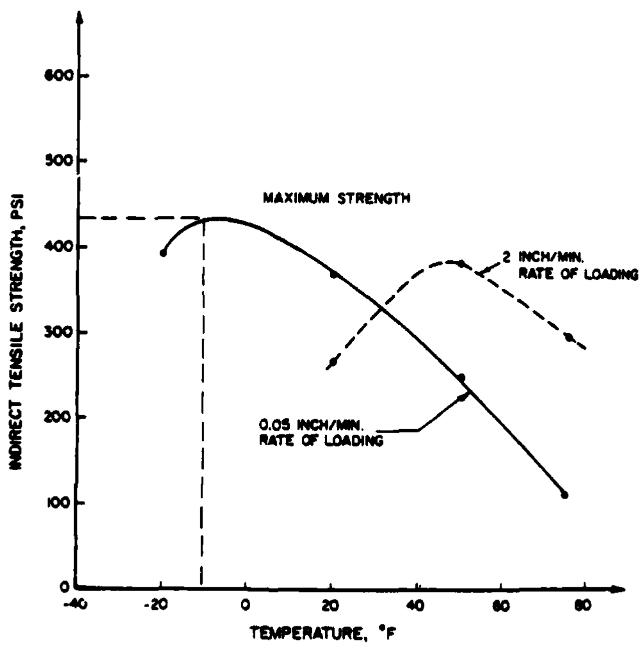


Figure 10. Tensile strength vs. temperature for AC surface top 1.5 inch.

```
1  PAV.SEC.NO.    1      SIERRA ARMY BASE

     TIME  OF  LOADING    ,SEC      =  3600.000

                                 MONTH  CODE
     JULY       AUG.       SEPT.     OCT.       NOV.       DEC.
       1          2          3         4          5          6
     JAN.       FEB.       MAR.      APR.       MAY.       JUNE
       7          8          9        10         11         12

                                  AIR TEMPERATURE
     ANNUAL AVERAGE          ,DEG.F                   =    49.500
     ANNUAL RANGE            ,DEG.F                   =    39.600
     DAILY  RANGE            ,DEG.F                   =    36.500

                                   FACTORS AFFECTING PAV. TEMP.
     ANNUAL AVE. SOLAR RAD. ,LANGLEYS                 =   455.000
     JULY   AVE. SOLAR RAD. ,LANGLEYS                 =   730.000
     ANNUAL AVE.WIND  VEL. ,MPH.                      =     6.300
     SURFACE ABSORBTIVITY                             =      .950
     DEPTH  FOR CALCUALTION,IN.                       =     0.000
     MIX.    CONDUCTIVITY    ,BTU-FT-HR-F.            =      .700
     MIX.   SPECIFIC  HEAT ,BTU-LB-F.                 =      .220
     MIX.  DENSITY          ,LB/FT3                   =   140.200

                                  ASPHALT PROPERTIES
     ORIG.  PENETRATION      ,DMM-5SEC.               =       90.
     PEN.   TEST TEMP.       ,DEG.F                   =       77.
     ORIG.  SOFTENING POINT,DEG.F                     =      121.
     THIN  FILM OVEN TEST ,PCT.ORIG.PEN.              =    72.000

                                  MIXTURE PROPERTIES
     PCT.   ASPHALT          ,BY WT.OF AGG.           =     7.527
     ASPH.  SPECIFIC GRAV.                            =     1.023
     AGG.   SPECIFIC  GRAV.                           =     2.660
     MIX.   AIR VOIDS       ,PERCENT                  =     6.200
     AGG.   VOL. CONCENTRATION -CALCULATED            =      .810
     COEF.  OF  CONTRACTION       TEMP(F)          ALPH(10**5)
                                   -70.                 1.000
                                     0.                 1.200
                                    70.                 1.400
                                   210.                 1.800
     COEF.  OF VARIATION OF ALPH                      =      .100
     MAX.   TEN.STRENGTH    ,PSI                      =   435.000
     COEF.  OF VARIATION OF MAX.STRENGTH              =      .200

                                  INPUT FATIGUE DATA
           FATIGUE CURVE                  N=A*(1.0/STRAIN)**B
     MIX.STIF.(PSI)          CONST.A                CONST.B
        .1000E+02            .1000E-01             .3600E+01
        .5000E+07            .8000E-12             .3950E+01
1  PAV.SEC.NO.    1      SIERRA ARMY BASE
```

Figure 11. Data used in temperature cracking program.

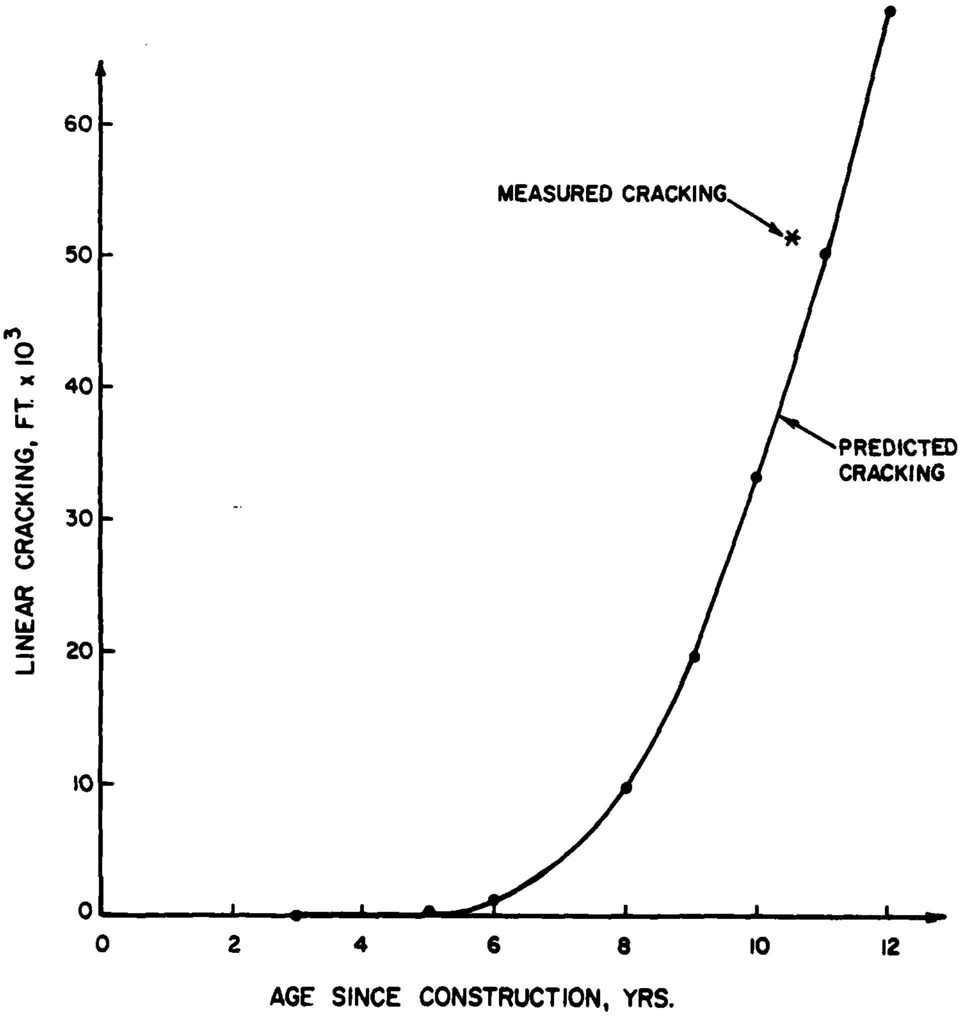


Figure 12. Predicted cracking using temperature cracking program.

Facility: Sierra Army Runway Feature: RC3

1. Overall Condition Rating - PCI = 61 ⇒ M&R zone = Routine, Major, or Overall

Excellent, Very Good, Good, Fair, Poor, Very Poor, Failed.

2. Variation of Condition Within Feature - PCI

a. Localized Random Variation	Yes,	No	
b. Systematic Variation:	Yes,	No	

3. Rate of Deterioration of Condition - PCI

a. Long-term period (since construction)	Low,	Normal,	High
b. Short-term period (1 year) unknown	Low,	Normal,	High

4. Distress Evaluation

a. Cause

Load Associated Distress	56	percent deduct values
Climate/Durability Associated	44	percent deduct values
Other (___) Associated Distress	___	percent deduct values

b. Moisture (Drainage) Effect on Distress	Minor,	Moderate,	Major
5. Load-Carrying Capacity Deficiency	No *	Yes	
6. Surface Roughness	Minor,	Moderate,	Major

7. Skid Resistance/Hydroplaning (runways only) unknown

No hydroplaning problems are expected

a. Mu-Meter

Transitional
Potential for hydroplaning
Very high probability

b. Stopping Distance Ratio

No hydroplaning anticipated
Potential not well defined
Potential for hydroplaning
Very high hydroplaning potential

c. Transverse Slope	Poor,	Fair,	Good,	Excellent
8. Previous Maintenance	Low,	Normal,	High	

9. Effect on Mission (Comments): * Pavement is structurally adequate, however alligator cracking causing 64% ~~of total deduct is due to weakened area~~ adjacent to climate caused cracks.

Figure 13. Airfield pavement condition evaluation summary.

M & R ZONE	PCI	RATING
ROUTINE	100	EXCELLENT
	85	VERY GOOD
ROUTINE, MAJOR, OVERALL,	70	GOOD
	55	FAIR
MAJOR, OVERALL	40	POOR
OVERALL	25	VERY POOR
	10 0	FAILED

Figure 14. Correlation of M&R zones with PCI and condition rating.

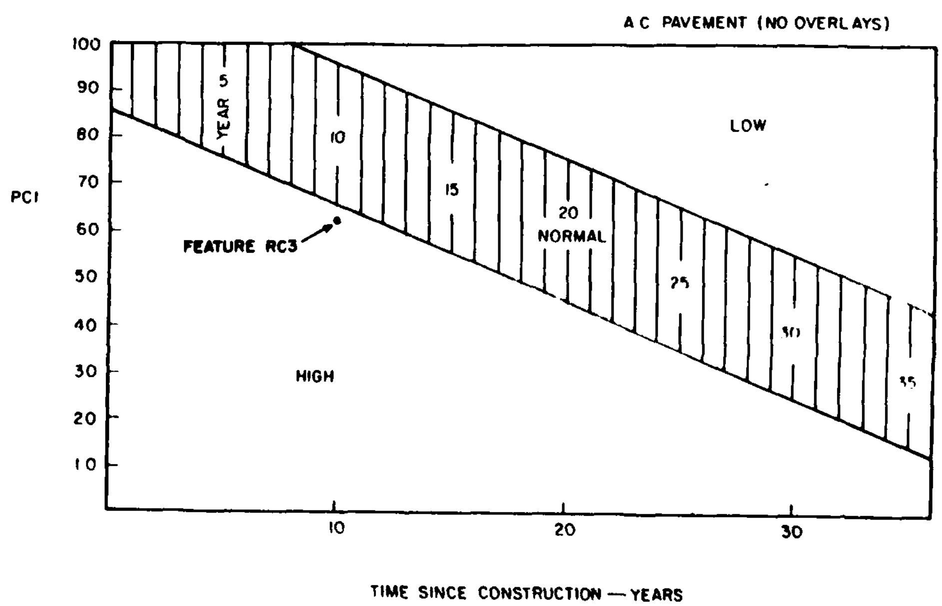
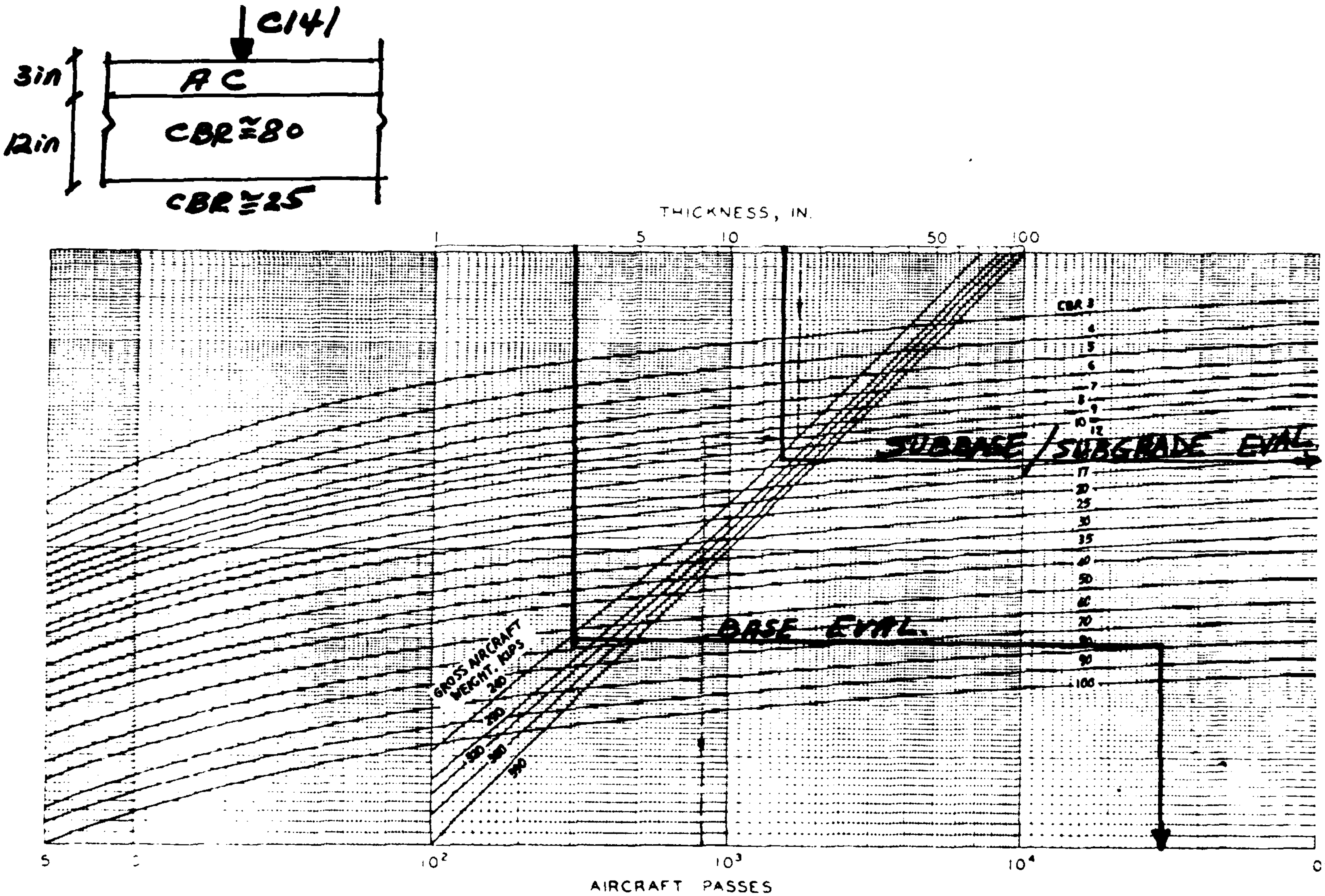


Figure 15. Rate of deterioration of AC pavements (no overlays).



FLEXIBLE PAVEMENT EVALUATION CURVES. C-141. TYPE A TRAFFIC AREAS

Figure 16. Evaluation of load carrying capacity.

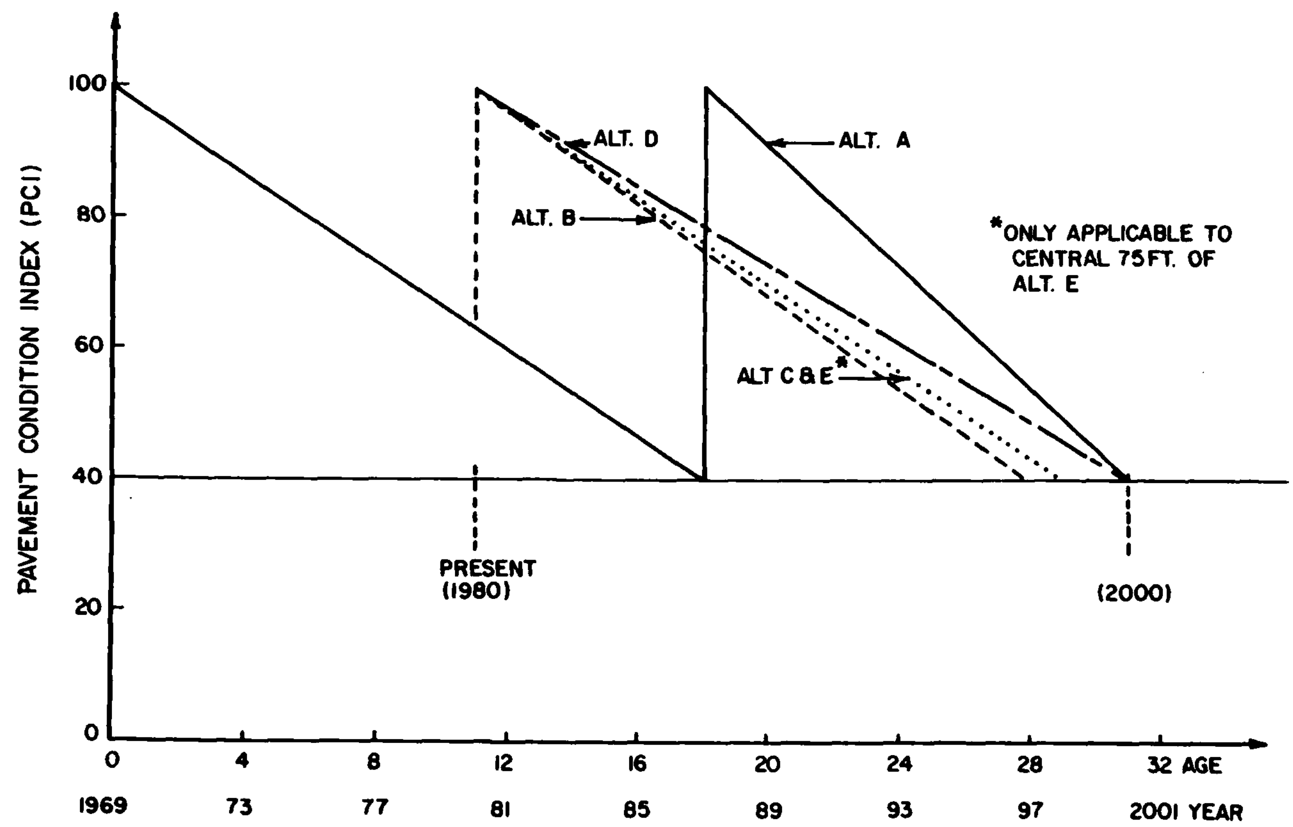
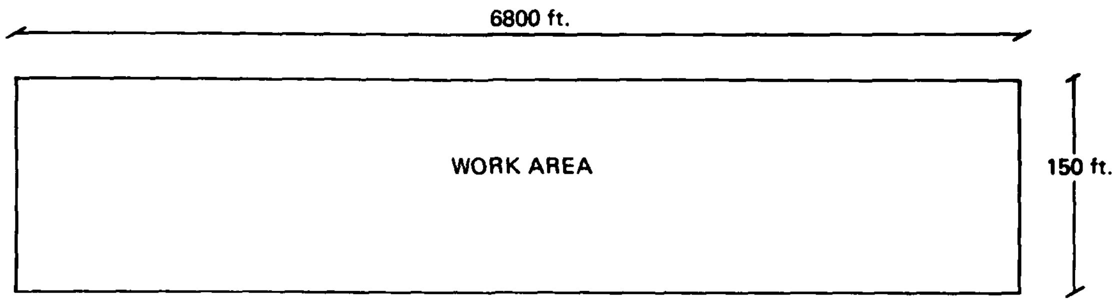


Figure 17. Expected PCI over time for each M&R alternative.

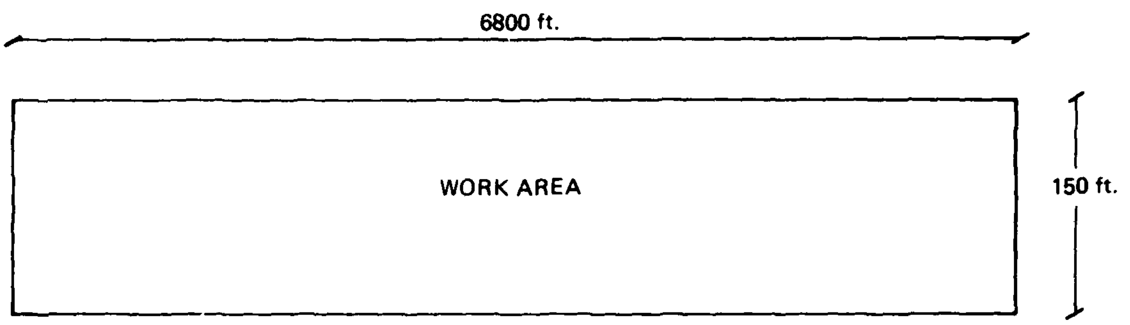


Work Summary: Continue to repair cracks as they appear or deteriorate. Cracks less than 1 inch wide will be sealed. Cracks over 1 inch wide will be patched.

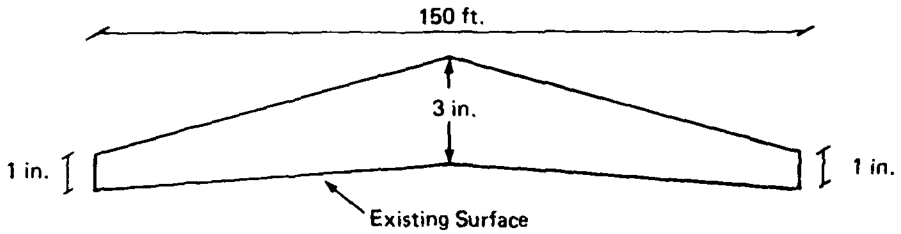
Initial Cost

1. Seal cracks less than 1 inch wide (See Est #1, Figure 19)	=	\$ 29,444
2. Patch cracks over 1 inch wide (See Est #2, Figure 19)	=	\$ 21,609
3. Patch alligator and slippage cracking (See Est #3, Figure 19)	=	\$ 5,361
4. Apply rejuvenator ($\simeq$ 0.1 gal/SY, $\simeq$ \$0.4/SY) 6800 x 150 x 1/9 x 0.4	=	\$ 45,333
	Total Initial Cost	\$101,747

Figure 18. Alternative A: continue crack seal to PCI=40 (1987), then overlay.



Work Summary: 1. Repair cracks (sealing & patching).
2. Overlay with AC as shown below.



Initial Cost

1. Seal all cracks less than 1 inch wide. Narrow cracks should be routed and cleaned. A space backer should be inserted before filling the cracks with a sealer. Assume half the medium severity cracks are less than 1 inch wide.

   Total length of cracks to be sealed
   = 16588 + 1/2 (25712) = 29444LF

   Crack seal = 29444 x \$1.0/LF = \$ 29,444

2. Saw cut and patch cracks over 1 inch wide. The patch should be approximately 6 inches wide and 3 inches deep.

   Quantity = 1/2 (25712) + 8753 = 21609LF

   Crack patch = 21609 x \$1.0/LF = \$ 21,609

3. Patch alligator and slippage cracking with 3-inch AC
   (248SF + 5051SF + 62SF) x \$1.0/SF = \$ 5,361

4. Tack coat — \$1.0/gal, Apply 0.1 gal/SY
   = @ \$0.1/SY

   6800 x 150 x 1/9 x .1 = \$ 11,333

5. New AC hot mix in place @ \$45/ton

   (6800 x 150 x 2/12) x 142 x 1/2000 x 45 = \$543,150

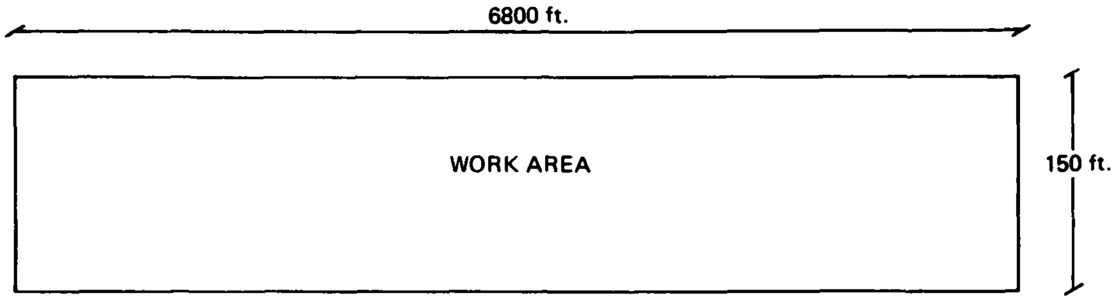
6. Apply rejuvenator, construction coat

   (≃ .075 gal/SY ≃ \$0.3/SY)

   6800 x 150 x 1/9 x 0.3 = \$ 34,000

Total Initial Cost \$644,897

Figure 19. Alternative B: overlay 1980.

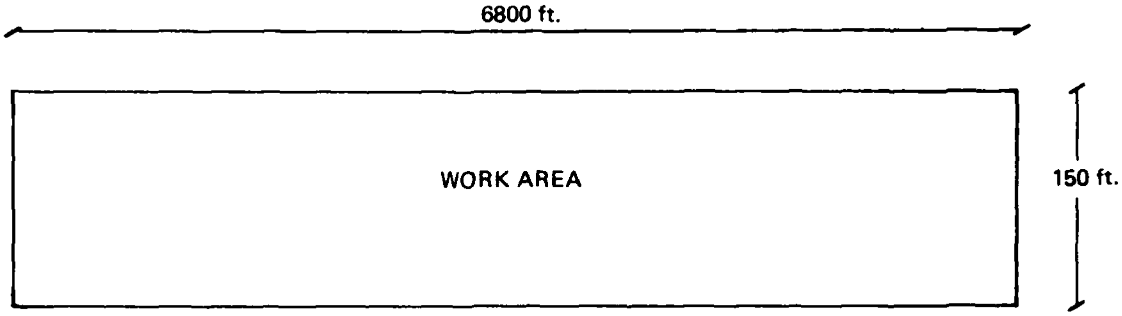


Work Summary: 1. Cold mill surface and store on base for future use.
2. Place new 3 inch hot AC.

Initial Cost

1. Cold mill AC surface @ \$0.75/SY/in.		
6800 x 150 x 1/9 x 3 x 0.75	=	\$ 255,000
2. Hauling and stockpiling cold-milled material Assume 1-mile haul @ \$0.5/ton mile		
6800 x 150 x 3/12 x 142 x 1/2000 x 0.5	=	\$ 9,053
3. Prime base course \$1.0/gal, Apply 0.2 gal/SY		
6800 x 150 x 1/9 x 0.2 x 1.0	=	\$ 22,667
4. New AC hot mix @ \$45.0/ton		
6800 x 150 x 3/12 x 142 x 1/2000 x 45	=	\$ 814,725
5. Apply rejuvenator, construction coat (≃ .075 gal/SY ≃ \$0.3/SY)		
6800 x 150 x 1/9 x .3	=	\$ 34,000
	Total Initial Cost	\$1,135,445

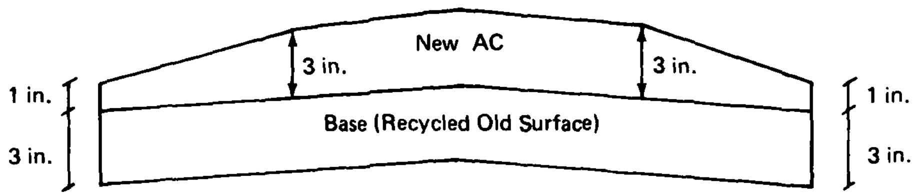
Figure 20. Alternative C: replace surface — 3-inch deep.



Work Summary: 1. Cold mill 150 ft width.

2. Recycle cold milled material and reuse as stabilized base.

3. Place new AC hot mix as shown below.



Initial Cost

1. Cold milling @ \$0.75/SY/in.

6800 x 150 x 1/9 x 3 x 0.75	=	\$ 255,000

2. Wind rowing mil. @ \$0.25/ton

6800 x 150 x 3/12 x 142 x 1/2000 x .25	=	\$ 4,526

3. Place cold-milled material as a base, compact & apply prime @ \$0.4/SY/in.

6800 x 150 x 1/9 x 0.4 x 3	=	\$ 136,000

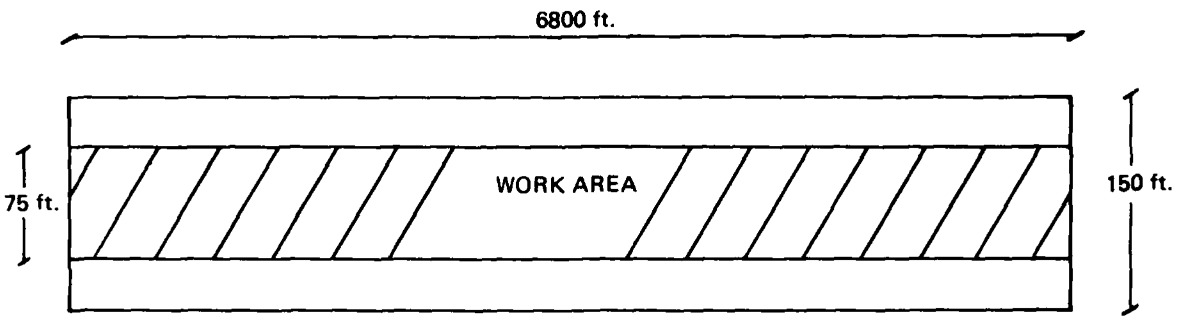
4. Place new AC hot mix as shown above @ \$45/ton

central 75: 6800 x 75 x 3/12 x 142 x 1/2000 x 45	=	\$ 407,362
outside: 6800 x 75 x 2/12 x 142 x 1/2000 x 45	=	\$ 271,575

5. Apply rejuvenator, construction coat (≃ .075 gal/SY @ ≃ \$0.3/SY)

6800 x 150 x 1/9 x 0.3	=	\$ 34,000
Total Initial Cost		\$1,108,463

Figure 21. Alternative D: recycle surface and use as base, add new surface.



Work Summary: 1. Cold mill central 75 ft — 3 in. depth and store on base for future use.
2. Place new 3 in. AC in central 75 ft.
3. Maintain cracks in outside edges.

Initial Cost

1. Cold mill central 75 ft — 3 inch @ $0.75/SY/in.		
6800 x 75 x 1/9 x 3 x .75	=	$127,500
2. Hauling and stockpiling cold-milled material assume 1 mile haul @ $.05/ton mile		
6800 x 75 x 3/12 x 142 x 1/2000 x .5	=	$ 4,526
3. Prime base course $1.0/gal, Apply 0.2 gal/SY		
6800 x 75 x 1/9 x .2 x 1.0	=	$ 11,333
4. New AC hot mix @ $45.0/ton		
6800 x 75 x 3/12 x 142 x 1/2000 x 45	=	$407,362
5. Repair cracks outside central 75 ft 18906 LF of crack x $1.0/LF (See Table 4)	=	$ 18,906
6. Apply rejuvenator, central 75 ft (≃ .075 gal/SY @ ≃ $0.3/SY)		
6800 x 75 x 1/9 x .3	=	$ 17,000
7. Apply rejuvenator, outside 75 ft (≃ 0.1 gal/SY @ ≃ $0.4/SY)		
6800 x 75 x 1/9 x .4	=	$ 22,666
	Total Initial Cost	$609,293

Figure 22. Alternative E: replace surface central 75 feet, crack seal outside.

REPORT DATE - 80/08/08.

COMPARISON OF M&R ALTERNATIVES
SIERRA
SECTION RU

	INFLATION RATE 10.00 PERCENT
ANALYSIS PERIOD - 20 YEARS	INTEREST RATE 10.00 PERCENT

ALTERNATIVE	DESCRIPTION	NET PRESENT COST
B	OVERLAY-1980	965563.
E	REPLACE SURFACE CENTERAL 75 FT,CRK SEAL OUTSIDE	1007500.
A	CONT CRK SEAL TO PCI=40(1987)THEN OVERLAY	1044139.
D	RECYCLE SURFACE AND USE AS BASE,ADD NEW SURFACE	1169796.
C	REPLACE SURFACE-3 INCH DEEP	1267111.

DETAILED COMPARISON OF M&R ALTERNATIVES

YEAR	ALT A COST	ALT A PRES COST	ALT B COST	ALT B PRES COST	ALT C COST	ALT C PRES COST	ALT D COST	ALT D PRES COST	ALT E COST	ALT E PRES COST
0 (FY80)	101747	101747	644897	644897	1135445	1135445	1108463	1108463	609293	609293
1 (FY81)	0	0	0	0	0	0	0	0	0	0
2 (FY82)	41403	41402	10000	10000	0	0	0	0	17473	17473
3 (FY83)	0	0	0	0	0	0	0	0	0	0
4 (FY84)	43213	43212	20000	20000	0	0	0	0	21392	21392
5 (FY85)	0	0	0	0	0	0	0	0	0	0
6 (FY86)	83960	83960	30000	29999	0	0	0	0	39002	39001
7 (FY87)	588483	588482	0	0	0	0	0	0	0	0
8 (FY88)	0	0	75333	75333	46333	46333	0	0	77819	77819
9 (FY89)	10000	9999	0	0	0	0	0	0	0	0
10 (FY90)	0	0	20000	20000	0	0	46333	46332	29449	29448
11 (FY91)	20000	20000	0	0	0	0	0	0	0	0
12 (FY92)	0	0	30000	29999	5000	5000	0	0	44925	44925
13 (FY93)	30000	29999	0	0	0	0	0	0	0	0
14 (FY94)	0	0	30000	30000	10000	10000	5000	5000	38103	38103
15 (FY95)	75333	75333	0	0	0	0	0	0	0	0
16 (FY96)	0	0	75333	75333	60333	60333	0	0	82566	82566
17 (FY97)	20000	20000	0	0	0	0	0	0	0	0
18 (FY98)	0	0	30000	30000	10000	9999	10000	9999	47478	47477
19 (FY99)	30000	30000	0	0	0	0	0	0	0	0
20 (FY00)	0	0	0	0	0	0	0	0	0	0
TOTAL	1044139	1044138	965563	965563	1267111	1267111	1169796	1169796	1007500	1007500
SALVAGE	0	0	0	0	0	0	0	0	0	0
PRES WORTH		1044138		965563		1267111		1169796		1007500

Figure 23. Life cycle costing of M&R alternatives.

Table 1
Summary of Linear Cracking for Entire Runway

Feature ID	Low Sev. Quant. LF	Low Sev. Dens. %	Med. Sev. Quant. LF	Med. Sev. Dens. %	High Sev. Quant. LF	High Sev. Dens. %	Total Crk. Quant. LF	Total Crk. Dens. %
RN1	215	3.82	44	.78			259	4.6
RN2	1348	.54	6506	2.6	2473	.99	10327	4.13
RS1	37	.65					37	0.65
RS2	3274	1.31	2666	1.06	2343	0.93	8283	3.33
RC1	328	2.91	329	2.92			657	5.83
RC2	1571	2.46	1030	1.61	800	1.25	3401	5.32
RC3	7711	2.05	12762	3.4	3074	.81	23547	6.26
RC4	2104	3.50	2375	3.95	63	0.1	4542	7.55
Total Crk. & Overall Dens.	16588	1.63	25712	2.52	8753	0.86	51053	5.01

Low Severity Cracking, % of Total Cracking = (16588/51053) x 100 = 32.5%

Med. Severity Cracking, % of Total Cracking = (25712/51053) x 100 = 50.4%

High Severity Cracking, % of Total Cracking = (8753/51053) x 100 = 17.1%

Table 2
Summary of Distresses Other Than Linear Cracking

Feature ID	Distress Type	Low Sev. Quant.	Low Sev. Dens.	Med. Sev. Quant.	Med. Sev. Dens.	High Sev. Quant.	High Sev. Dens.	Total Crk. Quant.	Total Crk. Dens.
RC2	Slippage* Cracking							248SF	0.38
RC3	Alligator Cracking	348	.09	3681	0.98	1022	.27	5051SF	1.34
RC4	Alligator Cracking			62	0.1			62SF	.1

*Slippage cracking has no severity levels.

Table 3
Predicted Cracks and Repair Costs for Entire Runway

Age Years	Year	Total Cracks, LF	Cracks to be Sealed, LF	Cracks to be Resealed, LF	Cost of Crack Repair (@ $1.0/LF)
11	80	51053	51053	0	51053
13	82	92456	41403	0	41403
15	84	135669	43213	0	43213
17	86	168576	32907	51053	83960
19	88	186863	18287	41403	59690
21	90	194291	7428	43213	50641
23	92	196498	2207	83960	86167
25	94	196971	473	59690	60163
27	96	197030	59	50641	50700
29	98	197050	20	86167	86187
31	00	197050	0	60163	60163
					$673,340

Table 4
Summary of Linear Cracking Outside the Central 75 Ft

Feature	Low Sev.		Med. Sev.		High Sev.		Total Crk.	
ID	Quant. LF	Dens. %	Quant. LF	Dens. %	Quant. LF	Dens. %	Quant. LF	Dens. %
RN1	215	3.82	44	.78			259	4.6
RN2	1348	.54	6506	2.6	2473	.99	10327	4.13
RS1	37	.65					37	.65
RS2	3274	1.31	2666	1.06	2343	.93	8283	3.33
Total Crk. & Overall Dens.	4874	0.96	9216	1.81	4816	0.94	18906	3.71

Low Severity Cracking, % of Total Cracking = (4874/18906) = 25.8

Med. Severity Cracking, % of Total Cracking = (9216/18906) = 48.7

High Severity Cracking, % of Total Cracking = (4816/18906) = 25.5

Table 5
Predicted Cracks and Repair Cost for Outside the Central 75 Ft

Age Years	Year	Total Cracks, LF	Cracks to be Sealed, LF	Cracks to be Resealed, LF	Cost of Crack Repair (@ $1.0/LF)
11	80	18906	18906	0	18906
13	82	36379	17473	0	17473
15	84	57771	21392	0	21392
17	86	77867	20096	18906	39002
19	88	92381	14514	17473	31987
21	90	100438	8057	21392	29449
23	92	103861	3423	39002	42425
25	94	104977	1116	31987	33103
27	96	105262	285	29449	29734
29	98	105315	53	42425	42478
31	00	105325	10	33103	33113
					$339,062

Table 6
Comparison of $/Unit Performance for Each M&R Alternative

Alternative	Net Present Cost	Area Between PCI & Min. PCI		$/Unit Performance
A	1,044,138	(63 - 40) x 7/2 + (100 - 40) x 13/2	= 470.5	2219
B	965,563	(100 - 40) x 17/2 + 0	= 510	1893
C	1,267,111	(100 - 40) x 18/2 + 0	= 540	2346
D	1,169,796	(100 - 40) x 20/2	600	1950
E*	1,007,500	(100 - 40) x 18/2	= 540	1866

*Only applicable to the central 75 ft.

APPENDIX A:
PCI COMPUTER OUTPUT

0

FEATURE IDENTIFICATION = RN1 SIERRA AFB CA

DATE SURVEYED 11/14/79. FLEXIBLE PAVEMENT.

FEATURE SIZE = 00005625 SF

TOTAL NO OF SAMPLE UNIT = 1

ALLOWABLE ERROR WITH 95% CONFIDENCE = 5

SAMPLE UNIT ID = 1
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	215	3.82	11.5
08	MEDIUM	44	0.78	10.0

PCI = 89

NO. OF RANDOM SAMPLE = 1

NO. OF ADDITIONAL SAMPLE = 0

PCI OF FEATURE -RN1 SIERRA AFB CA = 89 RATING = EXCELLENT

RECOMMEND EVERY SAMPLE UNITS TO BE SURVEYED.

ESTIMATED DISTRESS FOR FEATURE = RN1 SIERRA AFB CA

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	215	3.82	11.5
08	MEDIUM	44	0.78	10.0

0

0

FEATURE IDENTIFICATION = RN2 SIERRA AFB CA

DATE SURVEYED 11/14/79. FLEXIBLE PAVEMENT.

FEATURE SIZE = 00249375 SF

TOTAL NO OF SAMPLE UNIT = 45

ALLOWABLE ERROR WITH 95% CONFIDENCE = 5

SAMPLE UNIT ID = 4
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	MEDIUM	170	3.02	19.8

PCI = 80

SAMPLE UNIT ID = 10
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	MEDIUM	150	2.66	18.5

PCI = 82

SAMPLE UNIT ID = 16
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	123	2.18	8.3
08	MEDIUM	96	1.70	15.0

PCI = 85

SAMPLE UNIT ID = 22
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	49	0.87	4.9
08	MEDIUM	110	1.95	16.0

PCI = 79

SAMPLE UNIT ID = 28
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	25	0.44	3.6
08	MEDIUM	113	2.00	16.3

PCI = 80

SAMPLE UNIT ID = 32 *ADDITIONAL*
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	110	1.95	7.8
08	MEDIUM	37	0.65	9.1
08	HIGH	47	0.83	18.3

PCI = 82

SAMPLE UNIT ID = 34
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	3	0.05	1.2
08	MEDIUM	138	2.45	17.8
08	HIGH	392	6.96	46.3

PCI = 54

SAMPLE UNIT ID = 40
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	MEDIUM	268	4.76	24.3

PCI = 76

NO. OF RANDOM SAMPLE = 7

NO. OF ADDITIONAL SAMPLE = 1

PCI OF FEATURE -RN2 SIERRA AFB CA = 77 RATING = V. GOOD

RECOMMENDED MINIMUM OF 17 RANDOM SAMPLE UNITS TO BE SURVEYED.

STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED= 10.3

ESTIMATED DISTRESS FOR FEATURE = RN2 SIERRA AFB CA

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	1348	0.54	3.9
08	MEDIUM	6506	2.60	18.3
08	HIGH	2473	0.99	19.9

0

0

FEATURE IDENTIFICATION = RS1 SIERRA AFB CA

DATE SURVEYED 11/14/79. FLEXIBLE PAVEMENT.

FEATURE SIZE = 00005625 SF

TOTAL NO OF SAMPLE UNIT = 1

ALLOWABLE ERROR WITH 95% CONFIDENCE = 5

SAMPLE UNIT ID = 1
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	37	0.65	4.2

PCI = 96

NO. OF RANDOM SAMPLE = 1

NO. OF ADDITIONAL SAMPLE = 0

PCI OF FEATURE -RS1 SIERRA AFB CA = 96 RATING = EXCELLENT

RECOMMEND EVERY SAMPLE UNITS TO BE SURVEYED.

ESTIMATED DISTRESS FOR FEATURE = RS1 SIERRA AFB CA

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	37	0.65	4.2

0

0

FEATURE IDENTIFICATION = RS2 SIERRA AFB CA

DATE SURVEYED 11/14/79. FLEXIBLE PAVEMENT.

FEATURE SIZE = 00249375 SF

TOTAL NO OF SAMPLE UNIT = 45

ALLOWABLE ERROR WITH 95% CONFIDENCE = 5

SAMPLE UNIT ID = 4
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	2	0.03	0.7
08	MEDIUM	6	0.10	4.0
08	HIGH	126	2.24	29.0

PCI = 66

SAMPLE UNIT ID = 10
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	26	0.46	3.7
08	HIGH	76	1.35	22.9

PCI = 73

SAMPLE UNIT ID = 16
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	73	1.29	6.0
08	MEDIUM	106	1.88	15.7

PCI = 84

SAMPLE UNIT ID = 22
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	196	3.48	10.9
08	MEDIUM	88	1.56	14.4
08	HIGH	38	0.67	16.6

PCI = 78

SAMPLE UNIT ID = 28
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	46	0.81	4.7
08	MEDIUM	37	0.65	9.1
08	HIGH	37	0.65	16.3

PCI = 83

SAMPLE UNIT ID = 34
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	3	0.05	1.2
08	MEDIUM	147	2.61	18.3
08	HIGH	55	0.97	19.7

PCI = 76

SAMPLE UNIT ID = 40
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	171	3.04	10.0
08	MEDIUM	37	0.65	9.1
08	HIGH	38	0.67	16.6

PCI = 82

NO. OF RANDOM SAMPLE = 7

NO. OF ADDITIONAL SAMPLE = 0

PCI OF FEATURE -RS2 SIERRA AFD CA = 77 RATING = V. GOOD

RECOMMENDED MINIMUM OF 9 RANDOM SAMPLE UNITS TO BE SURVEYED.

STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED% 6.4

ESTIMATED DISTRESS FOR FEATURE = RS2 SIERRA AFD CA

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	3274	1.31	6.1
08	MEDIUM	2666	1.06	11.8
08	HIGH	2343	0.93	19.3

0

0

FEATURE IDENTIFICATION = RC1 SIERRA AFB CA

DAT= SURVEYED 11/14/79. FLEXIBLE PAVEMENT.

FEATURE SIZE % 00011250 SF

TOTAL NO OF SAMPLE UNIT % 2

ALLOWABLE ERROR WITH 95% CONFIDENCE = 5

SAMPLE UNIT ID = 1
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	183	3.25	10.4
08	MEDIUM	289	5.13	25.2

PCI = 75

SAMPLE UNIT ID = 2
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	145	2.57	9.1
08	MEDIUM	40	0.71	9.5

PCI = 91

NO. OF RANDOM SAMPLE = 2

NO. OF ADDITIONAL SAMPLE = 0

PCI OF FEATURE -RC1 SIERRA AFB CA = 83 RATING = V. GOOD

RECOMMEND EVERY SAMPLE UNITS TO BE SURVEYED.

ESTIMATED DISTRESS FOR FEATURE = RC1 SIERRA AFB CA

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	328	2.91	9.8
08	MEDIUM	329	2.92	19.5

0

0

FEATURE IDENTIFICATION = RC2 SIERRA AFB CA

DATE SURVEYED 11/14/79. FLEXIBLE PAVEMENT.

FEATURE SIZE Z 00063750 SF

TOTAL NO OF SAMPLE UNIT Z 11

ALLOWABLE ERROR WITH 95% CONFIDENCE = 5

SAMPLE UNIT ID = 1
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	363	6.45	16.9
08	MEDIUM	97	1.72	15.1

PCI = 81

SAMPLE UNIT ID = 3
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	95	1.68	7.0
08	MEDIUM	64	1.13	12.2
08	HIGH	88	1.56	24.6

PCI = 75

SAMPLE UNIT ID = 5
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	145	2.57	9.1
08	MEDIUM	102	1.81	15.5
08	HIGH	30	0.53	14.8

PCI = 80

SAMPLE UNIT ID = 7
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	44	0.78	4.6
08	MEDIUM	93	1.65	14.8
08	HIGH	94	1.67	25.4

PCI = 71

SAMPLE UNIT ID = 9 *ADDITIONAL*
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	23	0.40	3.5
08	MEDIUM	114	2.02	16.3
08	HIGH	142	2.52	30.5
15		132	2.34	21.9

PCI = 56

SAMPLE UNIT ID = 11
AREA OF SAMPLE,SF = 7500

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	152	2.02	8.0
08	MEDIUM	117	1.56	14.4
08	HIGH	128	1.70	25.6
15		60	0.80	10.5

PCI = 72

NO. OF RANDOM SAMPLE = 5

NO. OF ADDITIONAL SAMPLE = 1

PCI OF FEATURE -RC2 SIERRA AFB CA = 74 RATING = V. GOOD

RECOMMENDED MINIMUM OF 005 RANDOM SAMPLE UNITS TO BE SURVEYED.

STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED% 4.5

ESTIMATED DISTRESS FOR FEATURE = RC2 SIERRA AFB CA

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	1571	2.46	8.9
08	MEDIUM	1030	1.61	14.6
08	HIGH	800	1.25	22.1
15		248	0.38	7.3

0

O

FEATURE IDENTIFICATION = RC3 SIERRA AFB CA

DATE SURVEYED 11/14/79. FLEXIBLE PAVEMENT.

FEATURE SIZE % 00375000 SF

TOTAL NO OF SAMPLE UNIT % 67

ALLOWABLE ERROR WITH 95% CONFIDENCE = 5

SAMPLE UNIT ID = 6
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	152	2.70	9.4
08	MEDIUM	78	1.38	13.5
08	HIGH	77	1.36	23.0

PCI = 75

SAMPLE UNIT ID = 13
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	140	2.48	8.9
08	MEDIUM	74	1.31	13.1
08	HIGH	95	1.68	25.4

PCI = 74

SAMPLE UNIT ID = 20
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	182	3.23	10.4
08	MEDIUM	206	3.66	21.5
08	HIGH	76	1.35	22.9
01	LOW	18	0.32	11.1
01	MEDIUM	225	4.00	44.0
01	HIGH	24	0.42	28.3

PCI = 33

SAMPLE UNIT ID = 27
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	55	0.97	5.3
08	MEDIUM	183	3.25	20.4
08	HIGH	76	1.35	22.9
01	MEDIUM	17	0.30	18.5
01	HIGH	3	0.05	8.0

PCI = 61

SAMPLE UNIT ID = 34
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	81	1.44	6.3
08	MEDIUM	271	4.81	24.5
08	HIGH	69	1.22	21.8
01	LOW	10	0.17	8.1
01	MEDIUM	5	0.08	8.0
01	HIGH	45	0.80	34.3

PCI = 47

SAMPLE UNIT ID = 41
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	150	2.66	9.3
08	MEDIUM	182	3.23	20.3
08	HIGH	10	0.17	9.0

PCI = 80

SAMPLE UNIT ID = 48
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	57	1.01	5.5
08	MEDIUM	174	3.09	20.0
01	MEDIUM	240	4.26	44.7

PCI = 55

SAMPLE UNIT ID =   55
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	182	3.23	10.4
08	MEDIUM	262	4.65	24.0
01	LOW	19	0.33	11.3
01	MEDIUM	10	0.17	13.8
01	HIGH	66	1.17	38.5

PCI = 49

SAMPLE UNIT ID =   62
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	42	0.74	4.4
08	MEDIUM	293	5.20	25.4
08	HIGH	12	0.21	10.0

PCI = 75

NO. OF RANDOM SAMPLE =   9

NO. OF ADDITIONAL SAMPLE =   0

PCI OF FEATURE -RC3 SIERRA AFB CA   = 61   RATING = GOOD

RECOMMENDED MINIMUM OF   31 RANDOM SAMPLE UNITS TO BE SURVEYED.

STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED% 16.1

ESTIMATED DISTRESS FOR FEATURE = RC3 SIERRA AFB CA

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
01	LOW	348	0.09	6.3
01	MEDIUM	3681	0.98	29.2
01	HIGH	1022	0.27	24.2
08	LOW	7711	2.05	8.1
08	MEDIUM	12762	3.40	20.8
08	HIGH	3074	0.81	18.1

0

O

FEATURE IDENTIFICATION = RC4 SIERRA AFB CA

DATE SURVEYED 11/15/79. FLEXIBLE PAVEMENT.

FEATURE SIZE % 00060000 SF

TOTAL NO OF SAMPLE UNIT % 11

ALLOWABLE ERROR WITH 95% CONFIDENCE = 5

SAMPLE UNIT ID = 1
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	120	2.13	8.2
08	MEDIUM	219	3.89	22.1
01	MEDIUM	12	0.21	15.4

PCI = 75

SAMPLE UNIT ID = 3
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	233	4.14	12.1
08	MEDIUM	291	5.17	25.3
01	MEDIUM	35	0.62	24.8

PCI = 63

SAMPLE UNIT ID = 5
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	221	3.92	11.7
08	MEDIUM	157	2.79	19.0

PCI = 81

SAMPLE UNIT ID = 7
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	65	1.15	5.8
08	MEDIUM	190	3.37	20.7
08	HIGH	63	1.12	21.0
01	MEDIUM	15	0.26	17.3

PCI = 68

SAMPLE UNIT ID = 9
AREA OF SAMPLE,SF = 5625

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
08	LOW	219	3.89	11.6
08	MEDIUM	280	4.97	24.9

PCI = 75

NO. OF RANDOM SAMPLE = 5

NO. OF ADDITIONAL SAMPLE = 0

PCI OF FEATURE -RC4 SIERRA AFB CA = 72 RATING = V. GOOD

RECOMMENDED MINIMUM OF 7 RANDOM SAMPLE UNITS TO BE SURVEYED.

STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED= 6.9

ESTIMATED DISTRESS FOR FEATURE = RC4 SIERRA AFB CA

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY %	DEDUCT VALUE
01	MEDIUM	132	0.22	15.8
08	LOW	1830	3.05	10.0
08	MEDIUM	2425	4.04	22.5
08	HIGH	134	0.22	10.2

1	FEATURE	PCI	RATING
	RC3 SIERRA AFB CA	61	GOOD
	RC4 SIERRA AFB CA	72	V. GOOD
	RC2 SIERRA AFB CA	74	V. GOOD
	RN2 SIERRA AFB CA	77	V. GOOD
	RS2 SIERRA AFB CA	77	V. GOOD
	RC1 SIERRA AFB CA	83	V. GOOD
	RN1 SIERRA AFB CA	89	EXCELLENT
	RS1 SIERRA AFB CA	96	EXCELLENT

EOI ENCOUNTERED.

C>

APPENDIX B:
RESULTS OF AC LABORATORY TESTING

Table B1
Bituminous Mix Analysis

PROJECT Sierra Army Depot   JOB NO. ______   DATE 20 May 1980

SOURCE ______   SAMPLED BY ______   DATE REC'D ______

DESCRIPTION OF MATERIALS Asphalt Cement Slabs

LABORATORY NO. FPL 5864						
FIELD NO.						
OTHER IDENTIFICATION			Top Layer		Bottom Layer	
PAVEMENT CRITERION ( ) PSI TIRE PRESSURE						
SIZE OF SIEVE	SPECIFIED LIMITS	JOB MIX FORMULA (APPROVED)	Laboratory Samples*	Field Samples	Laboratory Samples*	Field Samples
1 INCH						
3/4 INCH			100.0		100.0	
1/2 INCH			94.3		93.7	
3/8 INCH			85.2		82.6	
NO. 4			71.6		63.8	
NO. 8			56.6		48.2	
NO. 16			41.0		35.2	
NO. 30			30.1		26.2	
NO. 50			21.6		19.0	
NO. 100			14.3		12.6	
NO. 200			8.6		7.6	
PERCENT BITUMEN			7.0	7.0	5.5	5.5
GRADE BITUMEN			--		--	
STABILITY (MARSHALL) LBS			5466		5153	
FLOW 0.01 INCHES			16		17	
PERCENT VOIDS TOTAL MIX			4.9	6.2	8.9	10.4
PERCENT VOIDS FILLED			75.8	70.6	57.3	52.8
DENSITY - LBS/CU FT			142.4	140.2	140.6	138.0
THEO DENSITY - LBS/CU FT			149.7		154.3	
STRIPPING, %			--		--	
SWELL, %			--		--	
AGG - SP GR			2.66		2.69	
AGG - % WATER ABSORPTION			1.6		2.0	

REMARKS:

			Test on Recovered Asphalt	
Penetration			15	13
Softening Pt. °C			71.2°C	75.0°C
Viscosity	Poises	140°F	113,038	268,884
	CST	225°F	20,321	27,535
	CST	275°F	2,230	3,451

TESTED BY: ______

CHECKED BY: ______

WES FORM NO. 1008
REV MARCH 1966

*Gyratory compaction at 200 psi, one degree, and 30 revolutions which is equivalent to 75 blows Marshall compaction effort

Table B2
Indirect Tensile Results

Sample No.	Maximum Load (lb)	Vertical Deformation (in.)	Temp (°F)	Load Rate (in./min)
1-1 top	1950	0.080	75	2.0
1-1 bottom	2400	0.095	75	2.0
1-2 top	2550	0.055	50	2.0
1-2 bottom	3000	0.048	50	2.0
1-3 top	2800	0.045	20	2.0
1-3 bottom	2200	0.065	20	2.0
2-1 top	1025	0.095	75	0.05
2-1 bottom	900	0.120	75	0.05
2-2 top	2470	0.080	50	0.05
2-2 bottom	1990	0.065	50	0.05
2-3 top	3650	0.055	20	0.05
2-3 bottom	3450	0.042	20	0.05
Additional top	4020	0.042	-20°F	0.05
Additional bottom	4025	0.040	-20°F	0.05

Table B3
Sample Size

Sample No.	Average Height (in.)	Average Diameter (in.)
Top 1-1	1.064	3.951
1-2	1.066	3.957
1-3	1.690	3.960
Top 2-1	1.485	3.960
2-2	1.587	3.966
2-3	1.587	3.955
Bottom 1-1	1.462	3.959
1-2	1.460	3.962
1-3	1.491	3.959
Bottom 2-1	1.601	3.962
2-2	1.561	3.949
2-3	1.577	3.957
Top-Additional	1.665	3.938
Bottom-Additional	1.723	3.917

Table B4
Computation of
Indirect Tensile Strength

Rate 2 in./min. $S = \frac{2P}{\pi \ell d}$

Temp	Sample ID	ℓ	d	P, lbs	S,Psi
75°F	Top 1-1	1.064	3.951	1950	295.30
50°F	Top 1-2	1.066	3.957	2550	384.86
20°F	Top 1-3	1.69	3.96	2800	266.352
75°F	Bottom 1-1	1.462	3.959	2400	263.93
50°F	Bottom 1-2	1.460	3.962	3000	330.17
20°F	Bottom 1-3	1.491	3.959	2200	237.27

Rate .05 in./min.

Temp	Sample ID	ℓ	d	P, lbs	S
75°F	Top 2-1	1.485	3.96	1025	110.96
50°F	Top 2-2	1.587	3.966	2470	249.83
20°F	Top 2-3	1.587	3.955	3650	370.2
-20°F	Top-additional	1.665	3.938	4020	390.32
75°F	Bottom 2-1	1.601	3.962	900	90.33
50°F	Bottom 2-2	1.561	3.949	1990	205.52
20°F	Bottom 2-3	1.577	3.957	3450	351.97
-20°F	Bottom-additional	1.723	3.917	4025	379.67

APPENDIX C: PROGRAM OUTPUT OF PCI PREDICTION FOR EACH M&R ALTERNATIVE

Alternative A. Overlay in 1987 — 2 inch average thickness.

```
SIERRA

  C141 AIRCRAFT ID
   0.0 AGE BETWEEN ORIGINAL CONSTRUCTION AND LAST OVERLAY
   3.0 TOTAL AC THICKNESS IN INCHES INCLUDING OVERLAYS
  15.0 TOTAL PAVEMENT THICKNESS ABOVE SUBGRADE
  80.0 CBR OF BASE
  25.0 CBR OF SUBGRADE

  18.0 YEARS TO OVERLAY FROM LAST CONST/OVERLAY
   2.0 THICKNESS OF OVERLAY


AGE SINCE OVERLAY        PCI
-----------------        ---
          0.0          100.0
          5.0           77.2
         10.0           54.4
         13.0           40.8
```

Alternative B. Overlay 1980 — 2-inch AC average thickness.

```
SIERRA

  C141 AIRCRAFT ID
   0.0 AGE BETWEEN ORIGINAL CONSTRUCTION AND LAST OVERLAY
   3.0 TOTAL AC THICKNESS IN INCHES INCLUDING OVERLAYS
  15.0 TOTAL PAVEMENT THICKNESS ABOVE SUBGRADE
  80.0 CBR OF BASE
  25.0 CBR OF SUBGRADE

  11.0 YEARS TO OVERLAY FROM LAST CONST/OVERLAY
   2.0 THICKNESS OF OVERLAY


AGE SINCE OVERLAY        PCI
-----------------        ---
          0.0          100.0
          5.0           82.2
         10.0           64.5
         15.0           46.7
         20.0           28.9
```

Alternatives C & E. Replace entire surface.

```
SIERRA

   C141 AIRCRAFT ID
    0.0 AGE BETWEEN ORIGINAL CONSTRUCTION AND LAST OVERLAY
    3.0 TOTAL AC THICKNESS IN INCHES INCLUDING OVERLAYS
   15.0 TOTAL PAVEMENT THICKNESS ABOVE SUBGRADE
   80.0 CBR OF BASE
   25.0 CBR OF SUBGRADE


 AGE SINCE LAST CONST/OVERLAY          PCI
 ----------------------------          ---
                0.0                   100.0
                5.0                    83.3
               11.0                    63.3
               20.0                    33.4
               25.0                    16.7
               31.0                     0.0
```

Alternative D. Reuse surface as base and add new 3 inch AC.

```
SIERRA

   C141 AIRCRAFT ID
    0.0 AGE BETWEEN ORIGINAL CONSTRUCTION AND LAST OVERLAY
    3.0 TOTAL AC THICKNESS IN INCHES INCLUDING OVERLAYS
   18.0 TOTAL PAVEMENT THICKNESS ABOVE SUBGRADE
  100.0 CBR OF BASE
   25.0 CBR OF SUBGRADE


 AGE SINCE LAST CONST/OVERLAY          PCI
 ----------------------------          ---
                0.0                   100.0
                5.0                    85.0
               10.0                    70.0
               15.0                    54.9
               20.0                    39.9
```

APPENDIX D:
PROGRAM OUTPUTS FOR PREDICTING FUTURE CRACKING

DISTRESS INPUT DATA

```
DISTRESS TYPE =      8.
AGE        =  11.00  YEARS
L          =   8.43
M          =  13.03
H          =   4.45
EARLIEST DISTRESS STARTING TIME =     0.0  YEARS
LATEST DISTRESS STARTING TIME   =    10.0  YEARS
DISTRESS AT INITIAL TIME =   .0100
EARLIEST TIME FROM L TO M       =     0.0  YEARS
LATEST TIME FROM L TO M         =     6.0  YEARS
EARLIEST TIME FROM M TO H       =     0.0  YEARS
LATEST TIME FROM M TO H         =     6.0  YEARS
MAXIMUM PREDICTION AGE          =    30.0  YEARS
```

```
OPTIMUM VALUES
     INITIAL TIME      =       0.0  YEARS
     TIME FROM L TO M =         1  YEARS
     TIME FROM M TO H =         3  YEARS
          MEAN                =  13.2719  YEARS
          STANDARD DEVIATION =   3.5158  YEARS
```

YEAR	L+M+H	L	M	H
0	.01	.01	0.00	0.00
1	.03	.02	.01	0.00
2	.07	.04	.03	0.00
3	.18	.11	.07	0.00
4	.42	.24	.17	.01
5	.93	.51	.39	.03
6	1.93	1.00	.86	.07
7	3.72	1.79	1.76	.18
8	6.69	2.97	3.30	.42
9	11.22	4.53	5.76	.93
10	17.60	6.38	9.29	1.93
11	25.91	8.30	13.88	3.72
12	35.88	9.97	19.22	6.69
13	46.92	11.04	24.66	11.22
14	58.20	11.28	29.32	17.60
15	68.85	10.65	32.29	25.91
16	78.11	9.26	32.97	35.88
17	85.55	7.44	31.19	46.92
18	91.06	5.31	27.35	58.20
19	94.83	3.77	22.22	68.85
20	97.21	2.38	16.73	78.11
21	98.60	1.39	11.67	85.55
22	99.35	.75	7.54	91.06
23	99.72	.37	4.51	94.83
24	99.88	.17	2.50	97.21
25	99.96	.07	1.28	98.60
26	99.98	.03	.61	99.35
27	99.99	.01	.27	99.72
28	100.00	.00	.11	99.88
29	100.00	.00	.04	99.96
30	100.00	.00	.01	99.98

CRACK PREDICTION FOR ENTIRE RUNWAY WIDTH
(NOTE 100% = 197050 LINEAR FEET OF CRK)

DISTRESS INPUT DATA

```
DISTRESS TYPE =       8.
AGE        =   11.00  YEARS
L          =    4.63
M          =    8.75
H          =    4.57
EARLIEST DISTRESS STARTING TIME =     0.0  YEARS
LATEST DISTRESS STARTING TIME   =     9.0  YEARS
DISTRESS AT INITIAL TIME =   .0100
EARLIEST TIME FROM L TO M       =     0.0  YEARS
LATEST TIME FROM L TO M         =     6.0  YEARS
EARLIEST TIME FROM M TO H       =     0.0  YEARS
LATEST TIME FROM M TO H         =     6.0  YEARS
MAXIMUM PREDICTION AGE          =    30.0  YEARS
```

```
OPTIMUM VALUES
     INITIAL TIME      =       0.0  YEARS
     TIME FROM L TO M =         1  YEARS
     TIME FROM M TO H =         2  YEARS
          MEAN                 =  14.5310  YEARS
          STANDARD DEVIATION =    3.8494  YEARS
```

YEAR	L+M+H	L	M	H
0	.01	.01	0.00	0.00
1	.02	.01	.01	0.00
2	.06	.03	.02	0.00
3	.14	.08	.05	.01
4	.31	.17	.11	.02
5	.67	.35	.25	.06
6	1.34	.67	.53	.14
7	2.52	1.19	1.02	.31
8	4.49	1.97	1.86	.67
9	7.54	3.05	3.15	1.34
10	11.96	4.42	5.02	2.52
11	17.95	5.99	7.47	4.49
12	25.54	7.59	10.41	7.54
13	34.54	9.00	13.58	11.96
14	44.52	9.97	16.59	17.95
15	54.85	10.33	18.97	25.54
16	64.86	10.01	20.30	34.54
17	73.93	9.07	20.35	44.52
18	81.62	7.69	19.09	54.85
19	87.71	6.09	16.76	64.86
20	92.23	4.51	13.78	73.93
21	95.36	3.13	10.61	81.62
22	97.38	2.03	7.64	87.71
23	98.61	1.23	5.15	92.23
24	99.30	.70	3.25	95.36
25	99.67	.37	1.92	97.38
26	99.85	.18	1.06	98.61
27	99.94	.08	.55	99.30
28	99.97	.04	.27	99.67
29	99.99	.01	.12	99.85
30	100.00	.01	.05	99.94

CRACK PREDICTION FOR OUTSIDE 75 FEET ONLY
(NOTE 100% = 105325 LINEAR FEET OF CRK)

APPENDIX E: FUTURE M&R COSTS FOR EACH M&R ALTERNATIVE

(A)

M & R ALTERNATIVE CONTINUE CRACK SEALING AND PATCHING TO A PCI = 40 (1987) THEN OVERLAY

ANALYSIS PERIOD 20 YEARS INTEREST RATE ______ %

INFLATION RATE ______ %

YEAR	M&R WORK DESCRIPTION	COST $	f	PRESENT WORTH $
80	SEAL & PATCH CRACKS	51,053		
80	PATCH ALLIGATOR CRACKING	5,361		
80	APPLY REJUVENATOR	45,333		
82	SEAL & PATCH CRACKS	41,403		
84	SEAL & PATCH CRACKS	43,213		
86	SEAL & PATCH CRACKS	83,960		
87	TACK COAT	11,333		
87	OVERLAY	543,150		
87	APPLY REJ. CONST. COAT	34,000		
89	SEAL & PATCH CRACKS	10,000 *		
91	SEAL & PATCH CRACKS	20,000 *		
93	SEAL & PATCH CRACKS	30,000 *		
95	SEAL & PATCH CRACKS	30,000 *		
95	APPLY REJUVENATOR	45,333		
97	SEAL & PATCH CRACKS	20,000 *		
99	SEAL & PATCH CRACKS	30,000 *		
			TOTAL	$

SALVAGE VALUE = = $______

PRESENT WORTH = $______

* ESTIMATED ASSUMING REFLECTION CRACKING

(B)

M & R ALTERNATIVE OVERLAY IN 1980 -- KEACH PCI = 40 (ABOUT 1996)

ANALYSIS PERIOD 20 **YEARS** **INTEREST RATE** ____ **%**

INFLATION RATE ____ **%**

YEAR	M&R WORK DESCRIPTION	COST $	f	PRESENT WORTH $
80	SEAL & PATCH CRACKS	51,053		
80	PATCH ALLIGATOR CRACKS	5,361		
80	TACK COAT	11,333		
80	OVERLAY	543,150		
80	APPLY REJ. CONST. COAT	34,000		
82	SEAL & PATCH CRACKS	10,000*		
84	SEAL & PATCH CRACKS	20,000*		
86	SEAL & PATCH CRACKS	30,000*		
88	SEAL & PATCH CRACKS	30,000*		
88	APPLY REJUVENATOR	45,333		
90	SEAL & PATCH CRACKS	20,000*		
92	SEAL & PATCH CRACKS	30,000*		
94	SEAL & PATCH CRACKS	30,000*		
96	SEAL & PATCH CRACKS	30,000*		
96	APPLY REJUVENATOR	40,333		
98	SEAL & PATCH CRACKS	30,000*		
			TOTAL	$

SALVAGE VALUE = **= $** ____

PRESENT WORTH = $ ____

*ESTIMATED ASSUMING REFLECTION CRACKING

(C)

M & R ALTERNATIVE REPLACE SURFACE COURSE (3INCH)

ANALYSIS PERIOD 20 **YEARS** **INTEREST RATE** ____ %

INFLATION RATE ____ %

YEAR	M&R WORK DESCRIPTION	COST $	f	PRESENT WORTH $
80	COLD MILL SURFACE	255,000		
80	HAULING MILLED MATERIAL	9,053		
80	PRIME BASE	22,667		
80	NEW 3INCH AC	814,725		
80	APPLY REJ. CONST. COAT	34,000		
88	SEAL & PATCH CRACKS	1,000*		
88	APPLY REJUVENATOR	45,333		
92	SEAL & PATCH CRACKS	5,000*		
94	SEAL & PATCH CRACKS	10,000*		
96	SEAL & PATCH CRACKS	15,000*		
96	APPLY REJUVENATOR	45,333		
98	SEAL & PATCH CRACKS	10,000*		
			TOTAL	$

SALVAGE VALUE = = $ ____

PRESENT WORTH = $ ____

* ESTIMATED ASSUMING REFLECTION CRACKING

Ⓓ

M & R ALTERNATIVE RECYCLE SURFACE AND USE AS BASE - ADD NEW SURFACE

ANALYSIS PERIOD 20 YEARS INTEREST RATE ____ %

INFLATION RATE ____ %

YEAR	M&R WORK DESCRIPTION	COST $	f	PRESENT WORTH $
80	COLD MILL	255,000		
80	WIND ROWING MILLED MAT'L	4,526		
80	PLACE MILLED MAT'L. AS			
	BASE & COMPACT & PRIME	136,000		
80	NEW AC SURFACE			
	- CENTRAL 75 FT.	407,362		
	- OUTSIDE 75 FT.	271,575		
80	APPLY REJ. CONST. COAT	34,000		
90	SEAL & PATCH CRACKS	1,000*		
90	APPLY REJUVENATOR	45,333		
94	SEAL & PATCH CRKS.	5,000*		
98	SEAL & PATCH CRACKS	10,000*		
			TOTAL	$

SALVAGE VALUE = = $ ____

PRESENT WORTH = $ ____

* ESTIMATED ASSUMING REFLECTION CRACKING

(E)

M & R ALTERNATIVE REPLACE KEEL (75 FT.) AND CONTINUE PATCH OUTSIDE 75 FT.

ANALYSIS PERIOD 20 **YEARS INTEREST RATE** ______ **%**

INFLATION RATE ______ **%**

YEAR	M&R WORK DESCRIPTION	COST $	f	PRESENT WORTH $
80	COLD MILL 75 FT.	127,500		
80	HAULING MILLED MAT'L.	4,526		
80	PRIME BASE	11,333		
80	NEW AC SURFACE	407,362		
80	SEAL & PATCH OUTSIDE CRKS	18,906		
80	APPLY REJ. CONST. COAT (75')	22,666		
80	APPLY REJ. OUTSIDE	17,000		
88	SEAL & PATCH CRACKS	500 *		
88	APPLY REJUVENATOR	22,666		
92	SEAL & PATCH CRACKS	2,500 *		
CENTRAL 75 FT. 94	SEAL & PATCH CRACKS	5,000 *		
96	SEAL & PATCH CRACKS	7,500 *		
96	APPLY REJUVENATOR	22,666		
98	SEAL & PATCH CRACKS	5,000 *		
82	SEAL & PATCH CRACKS	17,473		
84	SEAL & PATCH CRACKS	21,392		
86	SEAL & PATCH CRACKS	39,002		
88	SEAL & PATCH CRACKS	31,987		
88	APPLY REJUVENATOR	22,666		
OUTSIDE 75 FT. 90	SEAL & PATCH CRACKS	29,449		
92	SEAL & PATCH CRACKS	42,425		
94	SEAL & PATCH CRACKS	33,103		
96	SEAL & PATCH CRACKS	29,734		
96	APPLY REJUVENATOR	22,666		
98	SEAL & PATCH CRACKS	42478	TOTAL	$

SALVAGE VALUE = = $______

PRESENT WORTH = $______

*ESTIMATED ASSUMING REFLECTION CRACKING

CERL DISTRIBUTION

Chief of Engineers
ATTN: Tech Monitor
ATTN: DAEN-ASI-L (2)
ATTN: DAEN-CCP
ATTN: DAEN-CW
ATTN: DAEN-CWE
ATTN: DAEN-CWM-R
ATTN: DAEN-CWO
ATTN: DAEN-CWP
ATTN: DAEN-MP
ATTN: DAEN-MPC
ATTN: DAEN-MPE
ATTN: DAEN-MPO
ATTN: DAEN-MPR-A
ATTN: DAEN-RD
ATTN: DAEN-RDC
ATTN: DAEN-RDM
ATTN: DAEN-RM
ATTN: DAEN-ZC
ATTN: DAEN-ZCE
ATTN: DAEN-ZCI
ATTN: DAEN-ZCM

US Army Engineer Districts
ATTN: Library
Alaska
Al Batin
Albuquerque
Baltimore
Buffalo
Charleston
Chicago
Detroit
Far East
Fort Worth
Galveston
Huntington
Jacksonville
Japan
Kansas City
Little Rock
Los Angeles
Louisville
Memphis
Mobile
Nashville
New Orleans
New York
Norfolk
Omaha
Philadelphia
Pittsburgh
Portland
Riyadh
Rock Island
Sacramento
San Francisco
Savannah
Seattle
St. Louis
St. Paul
Tulsa
Vicksburg
Walla Walla
Wilmington

US Army Engineer Divisions
ATTN: Library
Europe
Huntsville
Lower Mississippi Valley
Middle East
Middle East (Rear)
Missouri River
New England
North Atlantic
North Central
North Pacific
Ohio River
Pacific Ocean
South Atlantic
South Pacific
Southwestern

Waterways Experiment Station
ATTN: Library

Cold Regions Research Engineering Lab
ATTN: Library

US Government Printing Office
Receiving Section/Depository Copies (2)

Defense Technical Information Center
ATTN: DDA (12)

Engineering Societies Library
New York, NY

FESA, ATTN: Library

ETL, ATTN: Library

Engr. Studies Center, ATTN: Library

Inst. for Water Res., ATTN: Library

Army Instl. and Major Activities (CONUS)
DARCOM - Dir., Inst., & Svcs.
ATTN: Facilities Engineer
ARRADCOM
Aberdeen Proving Ground
Army Matls. and Mechanics Res. Ctr.
Corpus Christi Army Depot
Harry Diamond Laboratories
Dugway Proving Ground
Jefferson Proving Ground
Fort Monmouth
Letterkenny Army Depot
Natick Research and Dev. Ctr.
New Cumberland Army Depot
Pueblo Army Depot
Red River Army Depot
Redstone Arsenal
Rock Island Arsenal
Savanna Army Depot
Sharpe Army Depot
Seneca Army Depot
Tobyhanna Army Depot
Tooele Army Depot
Watervliet Arsenal
Yuma Proving Ground
White Sands Missile Range

FORSCOM
FORSCOM Engineer, ATTN: AFEN-FE
ATTN: Facilities Engineers
Fort Buchanan
Fort Bragg
Fort Campbell
Fort Carson
Fort Devens
Fort Drum
Fort Hood
Fort Indiantown Gap
Fort Irwin
Fort Sam Houston
Fort Lewis
Fort McCoy
Fort McPherson
Fort George G. Meade
Fort Ord
Fort Polk
Fort Richardson
Fort Riley
Presidio of San Francisco
Fort Sheridan
Fort Stewart
Fort Wainwright
Vancouver Bks.

TRADOC
HQ, TRADOC, ATTN: ATEN-FE
ATTN: Facilities Engineer
Fort Belvoir
Fort Benning
Fort Bliss
Carlisle Barracks
Fort Chaffee
Fort Dix
Fort Eustis
Fort Gordon
Fort Hamilton
Fort Benjamin Harrison
Fort Jackson
Fort Knox
Fort Leavenworth
Fort Lee
Fort McClellan
Fort Monroe
Fort Rucker
Fort Sill
Fort Leonard Wood

INSCOM - Ch, Instl. Div.
ATTN: Facilities Engineer
Vint Hill Farms Station
Arlington Hall Station

WESTCOM
ATTN: Facilities Engineer
Fort Shafter

MDW
ATTN: Facilities Engineer
Cameron Station
Fort Lesley J. McNair
Fort Myer

HSC
HQ USAHSC, ATTN: HSLO-F
ATTN: Facilities Engineer
Fitzsimons Army Medical Center
Walter Reed Army Medical Center

USACC
ATTN: Facilities Engineer
Fort Huachuca
Fort Ritchie

MTMC
HQ, ATTN: MTMC-SA
ATTN: Facilities Engineer
Oakland Army Base
Bayonne MOT
Sunny Point MOT

US Military Academy
ATTN: Facilities Engineer
ATTN: Dept of Geography & Computer Science

USAES, Fort Belvoir, VA
ATTN: ATZA-DTE-EM
ATTN: ATZA-DTE-SU
ATTN: Engr. Library

Chief Inst. Div., I&SA, Rock Island.

USA ARRCOM, ATTN: Dir., Instl & Svc
TARCOM, Fac. Div.
TECOM, ATTN: DRSTE-LG-F
TSARCOM, ATTN: STSAS-F
NARAD COM, ATTN: DRDNA-F
AMMRC, ATTN: DRXMR-WE

HQ, XVIII Airborne Corps and Ft. Bragg
ATTN: AFZA-FE-EE

HQ, 7th Army Training Command
ATTN: AETTG-DEH (5)

HQ USAREUR and 7th Army
ODCS/Engineer
ATTN: AEAEN-EH (4)

V Corps
ATTN: AETVDEH (5)

VII Corps
ATTN: AETSDEH (5)

21st Support Command
ATTN: AEREH (5)

US Army Berlin
ATTN: AEBA-EN (2)

US Army Southern European Task Force
ATTN: AESE-ENG (5)

US Army Installation Support Activity Europe
ATTN: AEUES-RP

8th USA, Korea
ATTN: EAFE
Cdr, Fac Engr Act (8)
AFE, Yongsan Area
AFE, 2D Inf Div
AFE, Area II Spt Det
AFE, Cp Humphreys
AFE, Pusan
AFE, Taegu

DLA ATTN: DLA-WI

USA Japan (USARJ)
Ch, FE Div, AJEN-FE
Fac Engr (Honshu)
Fac Engr (Okinawa)

ROK/US Combined Forces Command
ATTN: EUSA-HHC-CFC/Engr

416th Engineer Command
ATTN: Facilities Engineering

Norton AFB
ATTN: AFRCE-MX/DEE

MC Team Distribution

USA ARRADCOM
ATTN: DRDAR-LCA-OK

Director of Facilities Engineering
Ft. Richardson, AK 99505
Miami, FL 34004

USA Liaison Detachment
ATTN: Library
New York, NY 10007

West Point, NY 10996
ATTN: Dept of Mechanics
ATTN: Library

HQDA (SGRD-EDE)

Chief of Engineers
ATTN: DAEN-MPO-B
ATTN: DAEN-MPZ-A
ATTN: DAEN-MPR (2)
ATTN: DAEN-RDL
ATTN: DAEN-ZCP

National Defense Headquarters
Director General of Construction
Ottawa, Ontario, Canada K1A OK2

Division of Building Research
National Research Council
Ottawa, Ontario, Canada K1A OR6

Airports and Const Services Dir
Technical Info Reference Center
Ottawa, Ontario, Canada K1A ON8

Ft. Belvoir, VA 22060
ATTN: ATSE-TD-TL (2)
ATTN: Learning Resource Center
ATTN: Kingman Bldg, Library
ATTN: Canadian Liaison Officer (2)
ATTN: British Liaison Officer (5)

US Army Foreign Science and
Tech Center
ATTN: Charlottesville, VA 22901
ATTN: Far East Office

Ft. Leavenworth, KS 66027
ATTN: ATZLCA-SA

Ft. Monroe, VA 23651
ATTN: ATEN-AD (3)
ATTN: ATEN-FE-ME
ATTN: ATEN-FE-BG (2)

Ft. McPherson, GA 30330
ATTN: AFEN-CD

Ft. Lee, VA 23801
ATTN: DRXMC-D (2)

USA-WES
ATTN: C/Structures
ATTN: Soils & Pavements Lab

6th US Army
ATTN: AFKC-EN

7th US Army
ATTN: AETTM-HRD-EHD

HQ, Combined Field Army (ROK/US)
ATTN: CFAR-EN
APO San Francisco 96358

US Army Engineer District
New York
ATTN: Chief, Design Br.
Pittsburgh
ATTN: Chief, ORPCD
ATTN: Chief, Engr Div
Philadelphia
ATTN: Chief, NAPEN-D

US Army Engineer District
Baltimore
ATTN: Chief, Engr Div
Norfolk
ATTN: Chief, NAOEN-M
ATTN: Chief, NAOEN-D
Huntington
ATTN: Chief, ORHED-F
Wilmington
ATTN: Chief, SAWCO-C
ATTN: Chief, SAWEN-D
Charleston
ATTN: Chief, Engr Div
Savannah
ATTN: Chief, SASAS-L
Jacksonville
ATTN: Const Div
Mobile
ATTN: Chief, SAMEN-D
ATTN: Chief, SAMEN-F
ATTN: Chief, SAMEN
Nashville
ATTN: Chief, ORNED-F
Memphis
ATTN: Chief, Const Div
ATTN: Chief, LMMED-D
Vicksburg
ATTN: Chief, Engr Div
Louisville
ATTN: Chief, Engr Div
Detroit
ATTN: Chief, NCEED-T
St. Paul
ATTN: Chief, ED-D
ATTN: Chief, ED-F
Chicago
ATTN: Chief, NCCCO-C
ATTN: Chief, NCCED-F
Rock Island
ATTN: Chief, Engr Div
ATTN: Chief, NCRED-F
St. Louis
ATTN: Chief, ED-D
Kansas City
ATTN: Chief, Engr Div
Omaha
ATTN: Chief, Engr Div
New Orleans
ATTN: Chief, LMNED-DG
Little Rock
ATTN: Chief, Engr Div
Fort Worth
ATTN: Chief, SWFED-D
ATTN: Chief, SWFED-F
Galveston
ATTN: Chief, SWGAS-L
ATTN: Chief, SWGCO-C
ATTN: Chief, SWGED-DC
Albuquerque
ATTN: Chief, Engr Div
Los Angeles
ATTN: Chief, SPLED-F
San Francisco
ATTN: Chief, Engr Div
Sacramento
ATTN: Chief, SPKED-D
ATTN: Chief, SPKCO-C
Far East
ATTN: Chief, Engr Div
Portland
ATTN: Chief, DB-6
ATTN: Chief, FM-1
ATTN: Chief, FM-2
Seattle
ATTN: Chief, NPSCO
ATTN: Chief, NPSEN-FM
ATTN: Chief, EN-DB-ST
Walla Walla
ATTN: Chief, Engr Div
Alaska
ATTN: Chief, NPASA-R

US Army Engineer Division
New England
ATTN: Chief, NEDED-T
ATTN: Laboratory
ATTN: Chief, NEDCD
Middle East (Rear)
ATTN: Chief, MEDED-T
North Atlantic
ATTN: Chief, NADEN
South Atlantic
ATTN: Laboratory
ATTN: Chief, SADEN-TC
ATTN: Chief, SADEN-TS
Huntsville
ATTN: Chief, HNDED-CS
ATTN: Chief, HNDED-M
ATTN: Chief, HNDED-SR
Lower Mississippi
ATTN: Chief, LMVED-G
Ohio River
ATTN: Laboratory
ATTN: Chief, Engr Div
Missouri River
ATTN: Chief, MRDED-G
ATTN: Laboratory
Southwestern
ATTN: Laboratory
ATTN: Chief, SWDED-MA
ATTN: Chief, SWDED-TG
South Pacific
ATTN: Laboratory
Pacific Ocean
ATTN: Chief, Engr Div
ATTN: FM&S Branch
ATTN: Chief, PODED-D
North Pacific
ATTN: Laboratory
ATTN: Chief, Engr Div

Facilities Engineer
Ft. Benning, GA 31905
ATTN: ATZB-FE-EP
ATTN: ATZB-FE-BG

AF/PREEU
Bolling AFB, DC 20332

AFESC/PRT
Tyndall AFB, FL 32403

Tinker AFB, OK 73145
2854 ABG/DEEE

Patrick AFB, FL 32925
ATTN: XRQ

McClellan AFB, CA 95652
2852 APG/DE

Little Rock AFB
ATTN: 314/DEEE

Naval Facilities Engr Command
ATTN: Code 04
ATTN: Code 2013 C
Alexandria, VA 22332

Port Hueneme, CA 93043
ATTN: Library (Code LO8A)
ATTN: Morell Library

Commander (Code 2636)
Naval Weapons Center
China Lake, CA 93555

Washington, DC
ATTN: Bldg Research Advisory Board
ATTN: Library of Congress (2)
ATTN: Federal Aviation Administration
ATTN: Dept of Transportation Library
ATTN: Transportation Research Board

Rock Island Arsenal (12)
DRCIS-RI-IB/M. Flaherty

Sierra Army Depot (12)
ATTN: FE/M. Balerviez

Shahin, Mohamed Y.
Pavement evaluation and repair recommendation, Sierra Army Depot, Amedee Air Strip. -- Champaign, IL : Construction Engineering Research Laboratory ; Springfield, VA : available from NTIS, 1980.
62 p. (Technical report ; M-283)

1. Sierra Army Depot, C.. 2. Air bases -- runways. 3. Pavements -- maintenance and repair. I. Title. II. Series: U.S. Army Construction Engineering Research Laboratory. Technical report ; M-283.